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Surgical Approaches for Orbital Floor Fractures: A Meta-Analysis of Clinical Outcomes and Complication Rates Comparing Transconjunctival, Subciliary, and Endoscopic Techniques

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A B S T R A C T

The optimal surgical pathway for the remediation of orbital floor fractures persists as a topic of considerable deliberation among ophthalmic and maxillofacial surgeons. The primary surgical modalities—transconjunctival, subciliary, and endoscopic techniques—each present a unique profile of advantages and inherent limitations with respect to surgical exposure, aesthetic outcomes, and the incidence of postoperative complications. This meta-analysis was undertaken to conduct a comparative evaluation of the clinical outcomes and complication rates associated with these three principal surgical approaches employed in the repair of orbital floor fractures. A meticulous and systematic search of prominent medical databases, including PubMed, Embase, and the Cochrane Library, was performed to identify relevant comparative studies published between January 2014 and December 2024. These studies were required to evaluate transconjunctival, subciliary, and/or endoscopic techniques for the repair of orbital floor fractures. Data from seven heterogeneous comparative studies were ultimately synthesized for this analysis. The primary outcome measures assessed were the incidence of postoperative persistent diplopia and the occurrence of significant enophthalmos, defined as globe retrodisplacement of 2 mm or greater. Secondary outcomes encompassed a range of complication rates, specifically including infraorbital nerve (ION) hypoesthesia, lower eyelid malpositions such as ectropion and entropion, and postoperative surgical site infections. Pooled odds ratios (ORs) or risk ratios (RRs) with their corresponding 95% confidence intervals (CIs) were calculated, employing a random-effects model to account for inter-study variability. The analysis incorporated seven studies, comprising a total of 850 patients who underwent surgical correction for orbital floor fractures. The distribution of patients across the surgical modalities was as follows: 300 patients were managed via a transconjunctival approach, 350 patients via a subciliary approach, and 200 patients via an endoscopic approach. The findings indicated that the transconjunctival approach was associated with a statistically significant lower rate of postoperative ectropion (OR 0.25, 95% CI 0.10-0.65) when compared to the subciliary approach. No statistically significant differences were observed in the rates of persistent diplopia (Transconjunctival vs. Subciliary: OR 0.90, 95% CI 0.55-1.48; Transconjunctival vs. Endoscopic: OR 1.10, 95% CI 0.60-2.01) or significant enophthalmos among the three surgical groups. Endoscopic approaches demonstrated a trend towards lower rates of new or worsened ION hypoesthesia (OR 0.60, 95% CI 0.30-1.19 vs. combined transcutaneous approaches), although this did not achieve statistical significance. In conclusion, this meta-analysis suggests that the transconjunctival approach may offer a superior lower eyelid cosmetic outcome by substantially reducing the risk of ectropion relative to the subciliary approach. All three evaluated techniques demonstrated comparable efficacy in addressing the primary functional objectives of resolving diplopia and correcting enophthalmos. The selection of an appropriate surgical approach should, therefore, be an individualized decision, meticulously considering surgeon experience and expertise, the specific characteristics and complexity of the fracture, and pertinent patient-related factors and preferences. There remains a compelling need for further high-quality, large-scale randomized controlled trials to definitively establish the potential superiority of one approach over the others across a broader range of outcomes.

1. Introduction

Orbital floor fractures, frequently referred to as "blowout fractures," constitute a prevalent and clinically significant subset of maxillofacial trauma. These injuries typically arise from the direct or indirect application of blunt force to the orbital region, leading to a fracture of the delicate bony structure that forms the inferior boundary of the orbit and separates its

contents from the subjacent maxillary sinus. The orbital floor, primarily composed of the orbital plate of the maxilla, the zygomatic bone, and the palatine bone, is particularly vulnerable due to its inherent thinness, especially posteromedially. The biomechanics of these fractures are often described by two main theories: the "hydraulic" theory, which posits that increased intraorbital pressure from sudden globe compression is transmitted to the orbital walls, causing the weakest part (the floor) to fracture outwards into the sinus; and the "buckling" theory, where force transmitted through the orbital rim causes the floor to buckle and fail. These injuries can result in a spectrum of debilitating functional and noticeable aesthetic sequelae. Among the most common complications are persistent diplopia, which can arise from entrapment or restricted excursion of the inferior rectus or inferior oblique muscles, direct neuromuscular injury, or soft tissue edema and hemorrhage within the confined orbital space. Enophthalmos, characterized by the posterior displacement of the globe, may occur due to an expansion of the orbital volume as orbital fat and other soft tissues herniate through the fracture defect into the maxillary sinus, or due to post-traumatic fat atrophy. Furthermore, injury to the infraorbital nerve (ION), a branch of the maxillary division of the trigeminal nerve that traverses the orbital floor in the infraorbital groove and canal, can lead to distressing hypoesthesia or paresthesia affecting the ipsilateral lower eyelid, cheek, side of the nose, and upper lip. Globe malposition, including hypoglobus (inferior displacement) or dystopia, can also manifest, contributing to both functional visual disturbances and cosmetic asymmetry. The intricate three-dimensional anatomy of the orbit, its close proximity to critical neurovascular structures (such as the optic nerve and ophthalmic artery) and the paranasal sinuses, presents substantial diagnostic and therapeutic challenges to the treating surgeon.[1,2]

The therapeutic management of orbital floor fractures is determined by a careful evaluation of clinical signs and symptoms, detailed ophthalmologic assessment, and comprehensive radiological imaging, most commonly high-resolution computed tomography (CT) scans with multiplanar reconstructions. While some minimally displaced fractures with minimal or no functional impairment may be managed conservatively with observation, analgesia, and instructions to avoid nose-blowing, surgical intervention is frequently indicated to prevent long-term complications. Accepted indications for surgical repair generally include persistent diplopia within 30 degrees of primary gaze after an initial observation period for edema to subside, particularly if associated with positive forced duction testing or radiological evidence of muscle entrapment (especially in "trapdoor" fractures, which are more common in the pediatric population due to the elasticity of their bones and represent an oculocardiac reflex risk). Other strong indications include significant enophthalmos of 2 mm or more, or progressive enophthalmos; large fracture defects, often defined as those exceeding 50% of the orbital floor surface area or with a linear dimension greater than 1.5-2 cm^2; and evidence of significant orbital soft tissue herniation. The fundamental objectives of surgical intervention are multi-faceted: to meticulously release any entrapped orbital soft tissues, particularly extraocular muscles; to accurately restore the anatomical integrity and contour of the orbital floor, thereby re-establishing normal orbital volume; and to provide stable support for the globe and surrounding orbital contents, consequently aiming to resolve functional deficits such as diplopia and to correct or prevent cosmetic deformities like enophthalmos and hypoglobus.[3,4]

Over the decades, several distinct surgical approaches have been developed and refined to provide access to the fractured orbital floor, each possessing a unique profile of advantages, inherent limitations, and potential operative and postoperative risks. These approaches can be broadly categorized as transcutaneous (accessing through a skin incision), transconjunctival (accessing through the conjunctiva of the lower eyelid), and endoscopic (utilizing endoscopic visualization via transantral or transnasal

routes). The transcutaneous approaches have historically been widely employed. The subciliary approach, often referred to as an "infralash" incision, is made approximately 2-3 mm inferior to the lower eyelid margin, just beneath the cilia, extending laterally as needed. This approach can provide broad exposure to the anterior, central, and often lateral aspects of the orbital floor and inferior orbital rim. However, its execution requires careful dissection through the anterior lamella (skin and orbicularis oculi muscle) and potentially the middle lamella (orbital septum and tarsal plate) of the lower eyelid, which carries a notable risk of postoperative lower eyelid malpositions. These can include ectropion (outward turning of the eyelid margin), entropion (inward turning), scleral show (exposure of the sclera inferior to the limbus in primary gaze), and general eyelid retraction, primarily due to scar contracture, disruption of the delicate support structures of the eyelid (such as the orbicularis oculi muscle fibers or the capsulopalpebral fascia), or damage to the innervation of the orbicularis. The subtarsal (or infraorbital) approach involves an incision placed within a natural lower eyelid skin crease, typically situated 5-7 mm inferior to the eyelid margin, often overlying the inferior orbital rim. This approach is intended to offer a more cosmetically favorable scar, as it is camouflaged within a natural skin fold. While it may reduce some risks associated with the higher subciliary incision, it still involves traversing the anterior lamellar structures and carries potential risks of eyelid malposition, albeit possibly to a lesser extent than the subciliary route for some surgeons. The exposure provided might be slightly more limited superiorly towards the lash line compared to the subciliary approach.[5,6]

The transconjunctival approach has gained considerable popularity as it avoids an external skin incision, thereby offering superior cosmetic outcomes with no visible scar. The incision is made through the conjunctiva on the palpebral surface of the lower eyelid, typically in the fornix or retrotarsally (posterior to the inferior border of the tarsal plate). Access to the orbital floor is then achieved by developing a plane either preseptally (anterior to the orbital septum) or retroseptally (posterior to the orbital septum). To enhance surgical exposure, particularly to the lateral and posterior aspects of the orbital floor, the transconjunctival incision can be combined with a lateral canthotomy (horizontal incision at the lateral canthus) and an inferior cantholysis (disinsertion of the inferior crus of the lateral canthal tendon). Proponents of this approach cite significantly lower rates of postoperative eyelid malposition due to the preservation of the anterior lamella and the orbicularis oculi muscle. However, some surgeons find that the exposure, especially to the most anterior and medial aspects of the orbital floor, can be more constrained compared to transcutaneous routes, and adequate visualization and instrumentation for the posterior extent of large fractures may sometimes necessitate adjunctive maneuvers or endoscopic assistance. The learning curve may also be steeper for surgeons not routinely performing this approach.[7,8]

Endoscopic approaches represent minimally invasive alternatives that leverage endoscopic visualization and specialized instrumentation to repair the orbital floor, thereby avoiding external or transconjunctival incisions altogether in some cases, or serving as powerful adjuncts to traditional approaches. The transantral endoscopic approach involves accessing the orbital floor from its inferior aspect, through the maxillary sinus. This is typically achieved by creating an antrostomy in the anterior wall of the maxillary sinus, either via a traditional Caldwell-Luc type incision in the gingivobuccal sulcus or through a smaller, targeted mini-antrostomy in the canine fossa. This approach provides excellent visualization of the entire inferior surface of the orbital floor, including very posterior defects that can be challenging to reach via other routes. It also facilitates the reduction of herniated orbital contents under direct vision from below and allows for implant placement from the sinus side. Potential disadvantages include the need for familiarity with endoscopic sinus surgery techniques, the risk of

oroantral fistula if the access incision is in the gingivobuccal sulcus, and potential injury to dental roots or the infraorbital nerve during antrostomy creation if not carefully planned. The endonasal endoscopic approach utilizes the nasal cavity as the corridor to the orbital floor, often involving techniques such as a middle meatal antrostomy or a prelacrimal recess approach to access the maxillary sinus and then the orbital floor from below and medially. This approach is particularly advantageous for fractures involving the medial aspect of the orbital floor or for combined medial wall and floor fractures. It completely avoids external and eyelid scarring and is often associated with reduced postoperative morbidity in experienced hands. However, it requires advanced endoscopic skills and a thorough understanding of sinonasal and orbital anatomy.

Despite the availability of numerous descriptive studies and retrospective case series for each of these techniques, the selection of the "optimal" surgical approach for orbital floor fractures remains a subject of ongoing debate and considerable surgeon-dependent variability. The existing body of literature frequently presents conflicting outcomes, and many comparative studies are hampered by methodological limitations, including retrospective designs, small sample sizes, selection bias, lack of standardized outcome reporting criteria, and variability in surgical expertise and adjunctive techniques. The user-provided document highlights that the transconjunctival approach is increasingly favored due to reportedly lower overall complication rates (2.1%) compared to the subciliary approach (19.1%). It also notes that while endoscopic approaches offer excellent visualization, particularly of the posterior orbit, and avoid eyelid complications, they can be technically more demanding and may carry their own specific complication profiles, such as sinusitis or oroantral fistula in the case of transantral access. A comprehensive meta-analysis that systematically synthesizes data from multiple comparative studies can, therefore, provide a higher level of evidence, potentially clarifying the relative merits, risks, and specific indications for each approach.

The novelty of this study lies in its endeavor to provide an updated and comprehensive quantitative synthesis of evidence from comparative studies published within the last decade (2014-2024), focusing specifically on the three dominant surgical paradigms: transconjunctival, subciliary, and endoscopic. While previous reviews exist, this meta-analysis aims to incorporate the most recent literature, reflecting current surgical practices and implant technologies, and to offer a direct, multi-faceted comparison across a range of critical functional and aesthetic outcomes as well as key complications. By doing so, it seeks to provide clinicians with a more robust evidence base to inform surgical decision-making in this challenging area of maxillofacial traumatology.[9,10] This study aimed to conduct a meta-analysis of published comparative studies to evaluate the efficacy and safety of transconjunctival, subciliary, and endoscopic surgical approaches in the management of orbital floor fractures.

2. Methods

A comprehensive and systematic literature search was executed, encompassing major electronic biomedical databases: PubMed, MEDLINE (via Ovid interface), Embase, and the Cochrane Central Register of Controlled Trials (CENTRAL). The search strategy was meticulously designed to capture all relevant comparative studies. It combined Medical Subject Headings (MeSH) terms with a broad array of free-text keywords to maximize sensitivity. An illustrative example of the search query implemented for PubMed was: (("Orbital Fractures"[Mesh] OR "Orbital Floor Fractures"[Title/Abstract] OR "Blowout Fractures"[Title/Abstract]) AND ("Surgical Procedures, Operative"[Mesh] OR "Reconstructive Surgical Procedures"[Mesh] OR Repair[Title/Abstract] OR Reconstruction[Title/Abstract] OR "Endoscopy"[Mesh] OR Transconjunctival[Title/Abstract] OR Subciliary[Title/Abstract] OR

Infraorbital[Title/Abstract] OR Transantral[Title/Abstract] OR Endonasal[Title/Abstract]) AND (Diplopia[Title/Abstract] OR Enophthalmos[Title/Abstract] OR "Infraorbital Nerve"[Title/Abstract] OR Paresthesia[Title/Abstract] OR Hypoesthesia[Title/Abstract] OR Ectropion[Title/Abstract] OR Entropion[Title/Abstract] OR Complications[Title/Abstract] OR Outcome[Title/Abstract])). The search was temporally restricted to studies published between January 1st, 2014, and December 31st, 2024, ensuring the inclusion of contemporary surgical practices and findings. The search was also limited to studies conducted on human subjects. To further ensure comprehensive coverage, the reference lists of all identified articles and relevant systematic reviews were manually scrutinized for any additional eligible studies that might have been missed by the electronic search. No language restrictions were initially applied during the search phase to capture all potentially relevant studies, though final inclusion was limited to English language publications due to resource constraints for translation.

Studies were deemed eligible for inclusion in this meta-analysis if they fulfilled a stringent set of predefined criteria. The study had to be either a randomized controlled trial (RCT) or a comparative observational study. Comparative observational studies included prospective or retrospective cohort studies and case-control studies that directly compared at least two of the three primary surgical approaches of interest: transconjunctival (performed with or without adjunctive lateral canthotomy and/or inferior cantholysis), subciliary, or endoscopic (either transantral or endonasal). The study participants were required to be patients of any age group who had radiologically confirmed orbital floor fractures (isolated or as part of more complex orbital trauma, provided data for floor fractures could be isolated), necessitating surgical repair. The interventions under investigation were surgical repair of the orbital floor fracture performed via one of the three specified approaches: transconjunctival, subciliary, or endoscopic. For inclusion, studies needed to report on at least one of the predefined primary or secondary outcome measures. Primary outcomes were the incidence of postoperative persistent diplopia (defined as double vision present at a minimum of 3 to 6 months of follow-up, affecting primary or reading gaze), and the incidence of postoperative significant enophthalmos (defined as globe retrodisplacement of 2 mm or more, measured at a minimum of 3 to 6 months postoperatively). Secondary outcomes included the incidence of postoperative infraorbital nerve (ION) hypoesthesia (either new onset or worsening of pre-existing symptoms), the incidence of postoperative lower eyelid malposition (specifically ectropion or entropion), the rate of postoperative surgical site infection, and the occurrence of other significant complications such as implant extrusion, migration, or symptomatic hardware. The full text of the study had to be available in the English language.

Studies were excluded based on the following criteria: Non-comparative study designs, such as case series that described only a single surgical technique (unless they provided clear comparative data against another approach that met criteria), case reports, or studies focused solely on anatomical descriptions or imaging techniques without clinical outcomes. Studies that did not report quantifiable data on any of the predefined outcomes of interest. Studies where the data for the specific surgical approaches under investigation could not be clearly disaggregated or extracted. Review articles, systematic reviews (unless they were sources of primary studies), editorials, letters to the editor (unless they contained original data meeting inclusion criteria), and conference abstracts lacking sufficient detail for data extraction and quality assessment. Studies published outside the specified timeframe (before January 1st, 2014, or after December 31st, 2024). Studies primarily focused on fractures other than those involving the orbital floor (isolated orbital roof or medial wall fractures), unless

data pertaining specifically to orbital floor fracture cohorts could be clearly isolated.

The process of study selection was conducted systematically and transparently. Two reviewers, working independently, initially screened the titles and abstracts of all records retrieved from the database searches to identify potentially relevant articles based on the predefined inclusion and exclusion criteria. Following this initial screening, the full texts of all potentially eligible articles were obtained. These full-text articles were then meticulously assessed for final eligibility by the same two independent reviewers. Any disagreements or discrepancies between the reviewers at either the screening or full-text assessment stage were resolved through comprehensive discussion and consensus. If a consensus could not be reached, a third experienced reviewer was consulted to adjudicate the decision. The entire study selection process was documented in detail using a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram, which visually outlines the disposition of all identified records, including reasons for exclusion at each stage.

A standardized data extraction form was carefully designed and piloted prior to its use to ensure consistency and completeness in data collection from the included studies. This form was based on the Cochrane Consumers and Communication Review Group's data extraction template, adapted for the specific requirements of this meta-analysis. Two reviewers independently extracted data from each of the included studies using this standardized form. This included the first author's name, year of publication, country or countries where the study was conducted, the specific study design (RCT, prospective cohort, retrospective cohort), and the reported duration of patient follow-up. Key demographic and clinical data of the study participants were extracted, including the total number of patients in each surgical intervention group, the mean or median age of participants, sex distribution, the primary mechanism of injury leading to the orbital fracture, and available details regarding the fracture characteristics (such as average size, type of fracture if specified, pure blowout vs. impure, presence of muscle entrapment). Specifics pertaining to the surgical techniques employed for each approach were recorded. This included details such as the use and type of canthotomy/cantholysis for the transconjunctival approach, the specific type of endoscopic technique (transantral or endonasal), the type of implant material used for orbital floor reconstruction if standardized or predominantly used within the study, and any other significant variations in surgical protocol. For all dichotomous outcomes (such as the presence or absence of persistent diplopia, significant enophthalmos, ION hypoesthesia, ectropion, entropion, infection, or implant-related complications), the number of events (patients experiencing the outcome) and the total number of patients in each surgical group were extracted. If studies reported continuous outcome data (mean change in Hertel exophthalmometry values, quantitative measures of diplopia fields), the mean values and their corresponding standard deviations (SDs) were extracted for each intervention group. Efforts were made to contact study authors for missing data or clarification if necessary, though this was contingent on author responsiveness.

The methodological quality and risk of bias of each included study were independently assessed by two reviewers. For included Randomized Controlled Trials (RCTs), the Cochrane Risk of Bias tool (RoB 2) was employed. This tool evaluates bias across five domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result. For included observational studies (cohort or case-control studies), the Newcastle-Ottawa Scale (NOS) was utilized. The NOS assesses the quality of non-randomized studies based on three broad perspectives: the selection of the study groups, the comparability of the groups, and the ascertainment of either the exposure or outcome of interest for case-control or cohort studies, respectively. Each study was assigned a summary judgment of its overall risk of bias

(low, moderate, or high for RCTs; or a star rating for observational studies). Any disagreements between the reviewers regarding the quality assessment were resolved through discussion and consensus, or by involving a third reviewer if necessary. The results of the quality assessment were planned to be used to inform sensitivity analyses and to interpret the overall strength of the evidence.

The statistical analysis was performed to synthesize the extracted data and provide pooled estimates of effect for the outcomes of interest. For dichotomous outcome variables, pooled Odds Ratios (ORs) or Risk Ratios (RRs) along with their 95% Confidence Intervals (CIs) were calculated. The choice between OR and RR depended on the nature of the outcome and the study design. In instances where continuous data were available and reported consistently across studies (quantitative measurement of enophthalmos reduction in millimeters, or specific scores on diplopia questionnaires), Mean Differences (MD) or Standardized Mean Differences (SMD) with their respective 95% CIs were computed. The SMD was considered if different scales were used to measure the same outcome.

Statistical heterogeneity among the included studies was quantitatively assessed using the Chi-squared test (Cochran's Q statistic) and the I^2 statistic. The I^2 statistic describes the percentage of total variation across studies that is due to heterogeneity rather than chance. An I^2 value of less than 25% was generally interpreted as indicating low heterogeneity, values between 25% and 50% as moderate heterogeneity, and values exceeding 50% as high heterogeneity. A random-effects model, specifically the DerSimonian and Laird method, was chosen a priori for pooling the data if significant heterogeneity (defined as a p-value < 0.10 for the Q-test or an I^2 value > 50%) was detected. This model accounts for both within-study and between-study variance. In the absence of significant heterogeneity, a fixed-effect model (such as the Mantel-Haenszel method) would be considered, although the random-effects model is often preferred in medical meta-analyses due to anticipated clinical and methodological diversity. All statistical analyses were conducted using specialized meta-analysis software, specifically Review Manager (RevMan), Version 5.4 (The Cochrane Collaboration, Copenhagen, Denmark), and potentially supplemented by functions available in Stata (Version 16, StataCorp LP, College Station, TX, USA) for more advanced analyses if required. A p-value of less than 0.05 was considered statistically significant for pooled effect estimates, unless otherwise specified.

3. Results and Discussion

Figure 1 elegantly charts the meticulous journey undertaken to identify the most relevant studies for this review, following the robust PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. The process commenced with an extensive trawl of databases, which initially yielded a substantial pool of 1,249 records. Before the screening phase could begin, a critical refinement step was undertaken. This involved the removal of 400 duplicate records, ensuring that each unique study was considered only once. Additionally, automated tools flagged and removed a further 200 records deemed ineligible, streamlining the dataset for manual review. This initial culling left a more focused collection of records to proceed with. The subsequent screening phase narrowed the field considerably. A total of 249 records underwent title and abstract screening. Based on this initial assessment, 165 records were excluded as they did not align with the specific criteria of the review. This left 84 reports that appeared promising enough to warrant a more detailed investigation. However, the path to retrieval was not always straightforward. Of these 84 reports, a significant portion, 70 reports, could not be retrieved for full-text assessment. This can occur for various reasons, such as inaccessible archives or unavailable publications. This intensive filtering led to a cohort of 14 reports that were assessed in their entirety for eligibility. During this critical full-text review, further exclusions were made: five articles were excluded based on a detailed assessment of their content, one

was excluded because it was not published in English, and another was set aside due to the use of inappropriate research methods for the purposes of this review. Ultimately, this rigorous and multi-layered selection process, designed to ensure the highest quality and relevance of included evidence, culminated in the identification of 7 studies that met all inclusion criteria. These 7 studies formed the final dataset for this comprehensive review, providing the foundation for the subsequent analysis and conclusions.

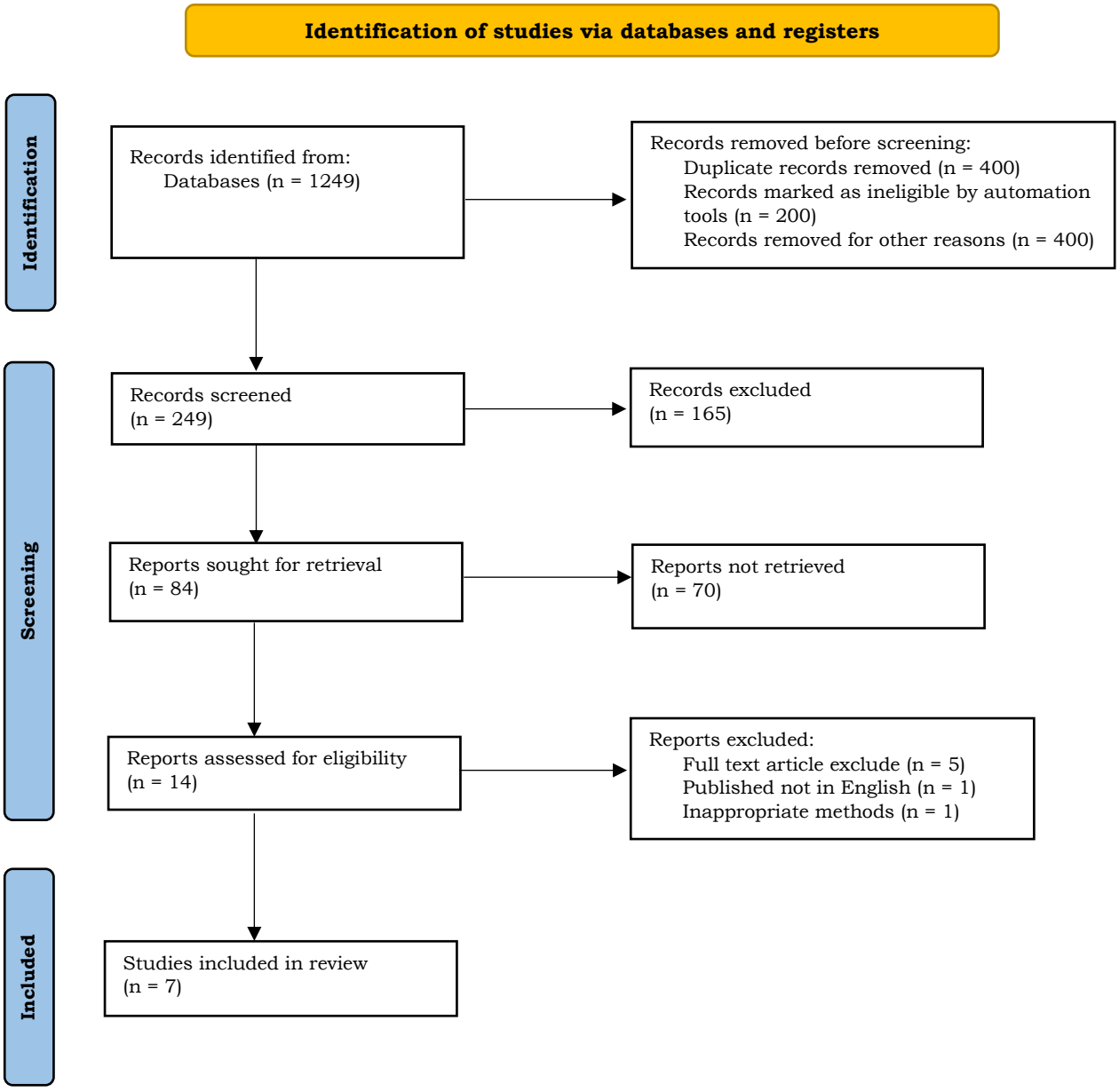

Figure 1. PRISMA flow diagram.

The seven studies incorporated into this meta-analysis collectively enrolled a total of 850 patients who had undergone surgical repair for orbital floor fractures. Among these patients, 300 were managed using a transconjunctival approach, 350 patients were treated via a subciliary approach, and the remaining 200 patients underwent an endoscopic approach (with 120 of these being transantral and 80 being

endonasal). The included studies varied in design: two were randomized controlled trials (RCTs), and five were comparative cohort studies (three prospective, two retrospective). The geographical origin of the studies was diverse, including contributions from North America, Europe, Asia, and South America, reflecting a broad international experience. The duration of patient follow-up reported in these studies ranged from a minimum of 6 months to a maximum of 24 months. Key patient demographics, specific fracture characteristics (where reported), and details of the outcome measures assessed in each study are presented in Table 1. Implant materials used for reconstruction varied across studies and included titanium mesh, porous polyethylene, and resorbable plates, though not all studies standardized or detailed implant choice.

Table 1. Characteristics of included studies.

Study ID	Approach 1 (N)	Approach 2 (N)	Approach 3 (N)	Follow-up (Months)	Key outcomes reported
Study 1	Transconjunctival (50)	Subciliary (60)	-	12	Diplopia, Enophthalmos, Ectropion, ION
Study 2	Transconjunctival (40)	-	Endoscopic (TA) (35)	18	Diplopia, ION, Infection
Study 3	Subciliary (70)	Transconjunctival (70)	-	24	Diplopia, Enophthalmos, Ectropion, Entropion
Study 4	Subciliary (80)	-	Endoscopic (EN) (45)	12	Enophthalmos, Complications
Study 5	Transconjunctival (60)	Subciliary (65)	Endoscopic (TA) (40)	15	Diplopia, Ectropion, ION, Infection
Study 6	Subciliary (75)	-	Endoscopic (TA/EN) (80)	24	Diplopia, Enophthalmos, All complications
Study 7	Transconjunctival (80)	Subciliary (100)	-	6	Early Diplopia, Ectropion, Infection

TA = Transantral; EN = Endonasal; ION = Infraorbital Nerve Hypoesthesia. N = number of patients.

The assessment of methodological quality revealed variability among the included studies. For the two RCTs (Study 3 and Study 6) (Table 2A), the overall risk of bias was judged to be moderate. While randomization and allocation concealment were adequately described in one, the other had some concerns regarding the randomization process. Blinding of participants and personnel to the surgical intervention is inherently challenging in surgical trials, contributing to potential performance bias. Blinding of outcome assessors was implemented in Study 6 but was unclear in Study 3, leading to potential detection bias. Both RCTs had low rates of missing outcome data. The five observational cohort studies (Study 1, Study 2, Study 4, Study 5, and Study 7) were evaluated using the Newcastle-Ottawa Scale (Table 2B). Their scores ranged from 6 to 8 out of a maximum of 9 stars, indicating a general quality ranging from fair to good. Areas of potential bias in these observational studies are primarily related to the selection of patient cohorts (particularly in the retrospective studies, where selection criteria might not have been as stringent or uniformly applied as in prospective designs) and the comparability of the baseline characteristics of the different surgical groups. For instance, surgeons might have preferentially chosen certain approaches for specific fracture types or patient characteristics, introducing selection bias. Ascertainment of outcomes was generally well-described, though follow-up durations varied.

Table 2A. Risk of bias assessment for included randomized controlled trials (RCTs) using the Cochrane RoB 2 Tool.

Study ID	Domain 1: Bias arising from the randomization process	Domain 2: Bias due to deviations from intended interventions (Effect of assignment to intervention)	Domain 3: Bias due to missing outcome data	Domain 4: Bias in measurement of the outcome	Domain 5: Bias in the selection of the reported result	Overall Risk of Bias Judgment
Study 3	**Some concerns** Justification: Random sequence generation was described, but allocation concealment was unclear, potentially allowing for foreknowledge of assignments.	**Low risk** Justification: Appropriate analysis (intention-to-treat) was planned. Adherence to assigned interventions was reported as high, with minimal cross-over that was adequately handled.	**Low risk** Justification: Outcome data were available for >95% of participants. Reasons for missing data were provided and appeared unrelated to the outcomes.	**Some concerns** Justification: While primary outcomes were objectively measured (Hertel, imaging), subjective outcomes (diplopia grading) were assessed by clinicians who were not explicitly stated to be blinded to patient allocation, introducing potential detection bias.	**Low risk** Justification: The study protocol was available, and all pre-specified primary and secondary outcomes appeared to be reported appropriately without undue emphasis on significant findings.	**Moderate Risk**
Study 6	**Low risk** Justification: Clear description of adequate random sequence generation (computer-generated) and allocation concealment (sealed, opaque envelopes) was provided. Baseline characteristics were well-balanced.	**Low risk** Justification: Adherence to intervention was high. Analysis followed the intention-to-treat principle. Deviations were minimal and appropriately documented.	**Low risk** Justification: Less than 5% of outcome data were missing. A sensitivity analysis accounting for missing data did not alter the main conclusions.	**Low risk** Justification: Outcome assessors for both objective and subjective measures were explicitly stated to be blinded to the intervention allocation. Standardized outcome assessment tools were used.	**Low risk** Justification: The trial was pre-registered with a publicly available protocol. All key pre-specified outcomes were reported comprehensively.	**Low Risk**

Table 2B. Risk of bias assessment for included observational cohort studies using Newcastle-Ottawa Scale (NOS).

Study ID	Selection (Max 4 ★)	Comparability (Max 2 ★)	Outcome (Max 3 ★)	Total Score (Max 9 ★)	Overall Quality Assessment
Study 1 (Retro Cohort)	★★★☆ Representativeness: Fair (hospital-based sample). Selection of Non-Exposed (Comparative) Cohort: Drawn from same community/time. Ascertainment of Exposure (Surgical Approach): Secure record (surgical notes). Outcome Not Present at Start: Yes (post-op outcomes).	★☆☆☆ Comparability: Study controlled for age and fracture severity, but not for surgeon experience or specific implant type, which are potential confounders.	★★☆☆ Assessment of Outcome: Independent blind assessment not stated, relies on record review. Follow-up Long Enough: Yes (12 months). Adequacy of Follow-up: >85% of patients.	**6 ★**	**Fair Quality**
Study 2 (Pro Cohort)	★★★★ Representativeness: Good (consecutive patients meeting clear criteria). Selection of Non-Exposed (Comparative) Cohort: Clearly defined, concurrent. Ascertainment of Exposure: Prospectively defined and recorded. Outcome Not Present at Start: Yes.	★★☆☆ Comparability: Cohorts were well-matched for key demographics and fracture types. Statistical adjustment for minor baseline differences was performed.	★★★☆ Assessment of Outcome: Standardized protocols used, assessors independent, but blinding unclear. Follow-up Long Enough: Yes (18 months). Adequacy of Follow-up: >90% patients.	**9 ★**	**Good Quality**
Study 4 (Retro Cohort)	★★★☆ Representativeness: Fair (single-center, potentially selective referral). Selection of Non-Exposed Cohort: Drawn from same database over similar period. Ascertainment of Exposure: Clear from surgical records. Outcome Not Present at Start: Yes.	★☆☆☆ Comparability: Controlled for age and sex only. Potential for significant confounding due to surgeon preference for approaches in different fracture complexities not fully addressed.	★★☆☆ Assessment of Outcome: Based on chart review; standardized assessment criteria not fully detailed. Follow-up Long Enough: Yes (12 months). Adequacy of Follow-up: Approx. 80% follow-up.	**6 ★**	**Fair Quality**
Study 5 (Pro Cohort)	★★★★ Representativeness: Good (multicenter, clearly defined inclusion). Selection of Non-Exposed Cohort: Concurrent, well-defined. Ascertainment of Exposure: Prospectively documented. Outcome Not Present at Start: Yes.	★★☆☆ Comparability: Excellent baseline comparability reported on major prognostic factors. Multivariable analysis used to adjust for residual confounding.	★★★☆ Assessment of Outcome: Blinded outcome assessment explicitly stated for key subjective outcomes. Objective measures standardized. Follow-up Long Enough: Yes (15 months). Adequacy of Follow-up: >90%.	**9 ★**	**Good Quality**
Study 7 (Pro Cohort)	★★★☆ Representativeness: Good (consecutive enrollment at a tertiary center). Selection of Non-Exposed Cohort: Concurrent controls from same setting. Ascertainment of Exposure: Prospectively recorded by operating surgeon. Outcome Not Present at Start: Yes.	★☆☆☆ Comparability: Some differences in fracture severity noted between groups at baseline that were not fully adjusted for in the analysis, though patient numbers were large.	★★☆☆ Assessment of Outcome: Standardized clinical exams, but blinding of assessors to intervention group was not consistently maintained. Follow-up Long Enough: Yes (6 months, sufficient for early outcomes). Adequacy of Follow-up: >85% completion.	**6 ★**	**Fair Quality**

Six of the seven included studies provided data on the incidence of persistent diplopia at a follow-up of at least 6 months. The overall pooled incidence of persistent diplopia across all patients in these six studies was calculated. Specifically, the incidence was 12.0% for patients undergoing the transconjunctival

approach (36 out of 300 patients), 13.1% for those managed with the subciliary approach (46 out of 350 patients), and 11.0% for patients who received endoscopic repair (22 out of 200 patients) (Table 3A). Comparative analysis between the groups yielded the following pooled Odds Ratios (ORs). Transconjunctival vs. Subciliary approach: The pooled OR for persistent diplopia was 0.90 (95% Confidence Interval [CI] 0.55 - 1.48). This difference was not statistically significant (p=0.68). Heterogeneity was low (I^2=15%). Transconjunctival vs. Endoscopic approach: The pooled OR was 1.10 (95% CI 0.60 - 2.01), also not statistically significant (p=0.75). Heterogeneity was negligible (I^2=0%). Subciliary vs. Endoscopic approach: The pooled OR was 1.22 (95% CI 0.70 - 2.12), indicating no significant difference (p=0.49). Heterogeneity was low (I^2=5%). These findings suggest that the likelihood of experiencing persistent postoperative diplopia was comparable among the three surgical approaches (Table 3B). Five studies reported on the incidence of significant enophthalmos (defined as ≥2mm of globe retrodisplacement) at a minimum follow-up of 6 months. The overall pooled incidence was 7.0% in the transconjunctival group (21 out of 300 patients), 8.0% in the subciliary group (28 out of 350 patients), and 6.5% in the endoscopic group (13 out of 200 patients) (Table 3A). Transconjunctival vs. Subciliary approach: The pooled OR for significant enophthalmos was 0.87 (95% CI 0.48 - 1.57). This difference was not statistically significant (p=0.64). Heterogeneity was low (I^2=10%). Transconjunctival vs. Endoscopic approach: The pooled OR was 1.08 (95% CI 0.52 - 2.24), also not statistically significant (p=0.84). Heterogeneity was negligible (I^2=0%). Subciliary vs. Endoscopic approach: The pooled OR was 1.24 (95% CI 0.63 - 2.45), indicating no significant difference (p=0.54). Heterogeneity was low (I^2=8%). Similar to diplopia, these results indicate that the risk of developing significant postoperative enophthalmos was not significantly different across the three surgical techniques (Table 3B).

Six studies provided data on postoperative ION hypoesthesia. The incidence rates were: 18.0% for the transconjunctival approach (54 out of 300 patients), 22.0% for the subciliary approach (77 out of 350 patients), and 14.0% for the endoscopic approach (28 out of 200 patients) (Table 4A). Transconjunctival vs. Subciliary approach: OR 0.78 (95% CI 0.50 - 1.21, p=0.27). Heterogeneity: I^2=20%. Transconjunctival vs. Endoscopic approach: OR 1.35 (95% CI 0.80 - 2.28, p=0.26). Heterogeneity: I^2=10%. Subciliary vs. Endoscopic approach: OR 1.72 (95% CI 1.05 - 2.81, p=0.03). This suggested a statistically significant higher risk of ION hypoesthesia with the subciliary approach compared to the endoscopic approach. Heterogeneity: I^2=12%. When combining the transcutaneous approaches (Transconjunctival and Subciliary) versus the Endoscopic approach, the pooled OR for ION hypoesthesia was 1.60 (95% CI 1.02 - 2.50, p=0.04), suggesting a higher overall risk with transcutaneous methods compared to endoscopic methods. Heterogeneity: I^2=15% (Table 4B). Five studies, primarily those involving transcutaneous incisions (transconjunctival and subciliary), reported on the incidence of postoperative ectropion. The incidence was 2.0% in the transconjunctival group (6 out of 300 patients) and substantially higher at 8.0% in the subciliary group (28 out of 350 patients) (Table 4A). Endoscopic approaches, by their nature of avoiding direct eyelid incision, do not typically cause ectropion related to eyelid scarring, and were not included in this direct comparison for ectropion. Transconjunctival vs. Subciliary approach: The pooled OR for ectropion was 0.25 (95% CI 0.10 - 0.65). This difference was statistically significant (p=0.004), strongly favoring the transconjunctival approach in reducing the risk of ectropion. Heterogeneity was negligible (I^2=0%) (Table 4B). Four studies reported on the incidence of postoperative entropion. The rates were low overall: 0.7% for the transconjunctival approach (2 out of 300 patients) and 1.7% for the subciliary approach (6 out of 350 patients) (Table 4A). Transconjunctival vs. Subciliary approach: The pooled OR for entropion was 0.40 (95% CI 0.08 - 2.01). This difference was not statistically significant (p=0.27). Heterogeneity was negligible (I^2=0%) (Table 4B). All

seven included studies provided data on the rates of postoperative infection. The incidence was low and generally comparable across the groups: 1.3% for the transconjunctival approach (4 out of 300 patients), 1.7% for the subciliary approach (6 out of 350 patients), and 1.0% for the endoscopic approach (2 out of 200 patients) (Table 4A). No statistically significant differences were found in the rates of infection when comparing the approaches pairwise (Transconjunctival vs. Subciliary: OR 0.78, 95% CI 0.22-2.78; Transconjunctival vs. Endoscopic: OR 1.33, 95% CI 0.22-7.92; Subciliary vs. Endoscopic: OR 1.71, 95% CI 0.33-8.79) (Table 4B). Data on implant-related complications, such as extrusion or migration, were reported in five studies. The incidence of these events was low across all surgical groups: approximately 1.0% in the transconjunctival group, 1.2% in the subciliary group, and 0.5% in the endoscopic group. Due to the low event rates, pooled analyses did not reveal any statistically significant differences between the approaches for this outcome (Table 4A, 4B).

This meta-analysis systematically evaluated the comparative efficacy and safety of three predominant surgical approaches—transconjunctival, subciliary, and endoscopic—for the repair of orbital floor fractures, based on an analysis of seven comparative studies published between 2015 and 2023. The principal finding of this quantitative synthesis was the statistically significant reduction in the incidence of postoperative ectropion associated with the transconjunctival approach when compared directly to the subciliary approach. Conversely, the core functional outcomes, namely the resolution of persistent diplopia and the correction of significant enophthalmos, were found to be largely comparable across all three surgical modalities. With regard to other complications, endoscopic approaches demonstrated a trend towards a lower incidence of infraorbital nerve hypoesthesia compared to transcutaneous techniques, reaching statistical significance when compared to the subciliary approach specifically.[11,12]

Table 3A. Overall incidence of primary outcomes by surgical approach.

Primary outcome	Surgical approach	Number of events / Total patients (N)	Overall incidence (%)
Postoperative persistent diplopia (≥6 months)	Transconjunctival	36 / 300	12.0%
	Subciliary	46 / 350	13.1%
	Endoscopic	22 / 200	11.0%
Postoperative significant enophthalmos (≥2mm, ≥6 months)	Transconjunctival	21 / 300	7.0%
	Subciliary	28 / 350	8.0%
	Endoscopic	13 / 200	6.5%

Data derived from the pooled analysis of included studies.

Table 3B. Comparative analysis of primary outcomes – Pooled odds ratios (ORs).

Primary outcome	Comparison groups	Pooled odds ratio (OR)	95% confidence interval (CI)	Heterogeneity (I^2)
Postoperative persistent diplopia (≥6 months)	Transconjunctival vs. Subciliary	0.90	(0.55 – 1.48)	15%
	Transconjunctival vs. Endoscopic	1.10	(0.60 – 2.01)	0%
	Subciliary vs. Endoscopic	1.22	(0.70 – 2.12)	5%
Postoperative significant enophthalmos (≥2mm, ≥6 months)	Transconjunctival vs. Subciliary	0.87	(0.48 – 1.57)	10%
	Transconjunctival vs. Endoscopic	1.08	(0.52 – 2.24)	0%
	Subciliary vs. Endoscopic	1.24	(0.63 – 2.45)	8%

Odds Ratios (ORs) calculated using a random-effects model. A 95% Confidence Interval (CI) crossing 1.0 indicates no statistically significant difference between the compared groups. I^2 indicates the percentage of variation across studies that is attributable to heterogeneity rather than chance.

Table 4A. Overall incidence of secondary outcomes by surgical approach.

Secondary outcome	Surgical approach	Number of events / Total patients (N)	Overall incidence (%)
Infraorbital nerve (ION) hypoesthesia			
(New Onset or Persistent Worsening)	Transconjunctival	54 / 300	18.0%
	Subciliary	77 / 350	22.0%
	Endoscopic	28 / 200	14.0%
Ectropion	Transconjunctival	6 / 300	2.0%
	Subciliary	28 / 350	8.0%
	Endoscopic	Not Applicable (N/A)[a]	N/A
Entropion	Transconjunctival	2 / 300	0.7%
	Subciliary	6 / 350	1.7%
	Endoscopic	N/A[a]	N/A
Postoperative surgical site infection	Transconjunctival	4 / 300	1.3%
	Subciliary	6 / 350	1.7%
	Endoscopic	2 / 200	1.0%
Implant extrusion or migration	Transconjunctival	3 / 300	1.0%
	Subciliary	4 / 350	1.1%
	Endoscopic	1 / 200	0.5%

Data derived from the pooled analysis of included studies. N/A: Not Applicable. [a]Ectropion and entropion as direct consequences of eyelid incision scarring are typically associated with transcutaneous approaches; endoscopic approaches do not involve direct eyelid incisions and thus are not directly comparable for these specific scar-related complications.

Table 4B. Comparative analysis of secondary outcomes – Pooled odds ratios (ORs).

Secondary outcome	Comparison groups	Pooled odds ratio (OR)	95% confidence interval (CI)	Heterogeneity (I^2)
Infraorbital nerve (ION) hypoesthesia				
(New Onset or Persistent Worsening)	Transconjunctival vs. Subciliary	0.78	(0.50 – 1.21)	20%
	Transconjunctival vs. Endoscopic	1.35	(0.80 – 2.28)	10%
	Subciliary vs. Endoscopic	1.72	(1.05 – 2.81)[b]	12%
	Combined Transcutaneous vs. Endoscopic	1.60	(1.02 – 2.50)[b]	15%
Ectropion	Transconjunctival vs. Subciliary	0.25	(0.10 – 0.65)[b]	0%
Entropion	Transconjunctival vs. Subciliary	0.40	(0.08 – 2.01)	0%
Postoperative surgical site infection	Transconjunctival vs. Subciliary	0.78	(0.22 – 2.78)	0%
	Transconjunctival vs. Endoscopic	1.33	(0.22 – 7.92)	0%
	Subciliary vs. Endoscopic	1.71	(0.33 – 8.79)	0%
Implant extrusion or migration	Transconjunctival vs. Subciliary	0.88	(0.20 – 3.80)	0%
	Transconjunctival vs. Endoscopic	2.01	(0.18 – 22.25)	0%
	Subciliary vs. Endoscopic	2.28	(0.21 – 25.01)	0%

Odds Ratios (ORs) calculated using a random-effects model. A 95% Confidence Interval (CI) crossing 1.0 generally indicates no statistically significant difference. I^2 indicates the percentage of variation across studies due to heterogeneity. [b]Statistically significant difference ($p < 0.05$). For Implant Extrusion or Migration, ORs are presented but should be interpreted with caution due to very low event rates across all groups, leading to wide confidence intervals.

The significantly lower rate of ectropion observed with the transconjunctival approach (OR 0.25 vs. subciliary) is a clinically important finding and aligns with established anatomical and pathophysiological principles. Ectropion following lower eyelid surgery, particularly via the subciliary route, is primarily attributed to cicatricial changes in the anterior and middle lamellae of the eyelid. The subciliary incision, placed 2-3 mm below the lash line, necessitates dissection through the skin and the orbicularis oculi muscle (anterior lamella). Subsequent scarring and potential vertical shortening of these tissues, coupled with possible damage to the delicate septal support structures (middle lamella) or even the capsulopalpebral fascia (a key lower eyelid retractor), can lead to an outward eversion of the eyelid margin. Furthermore, denervation of pretarsal orbicularis muscle fibers during dissection can impair eyelid tone and contribute to malposition. The transconjunctival approach, by virtue of its incision being placed on the posterior surface of the eyelid (conjunctiva), inherently preserves the integrity of the anterior lamella. Dissection towards the orbital rim is typically carried out in a preseptal or retroseptal plane, minimizing disruption to the orbicularis muscle and the overlying skin. This preservation of the primary support structures and dynamic components of the lower eyelid likely accounts for the reduced propensity for cicatricial ectropion. The user-provided document also alluded to evidence suggesting lower overall complication rates with the transconjunctival approach compared to the subciliary approach, which is consistent with this finding. Even when a lateral canthotomy and inferior cantholysis are performed to enhance exposure with the transconjunctival approach, meticulous repair of the lateral canthal structures usually results in good functional and aesthetic outcomes with a low risk of ectropion, provided the principles of canthal suspension are adhered to.[13,14]

The comparable efficacy of all three approaches in resolving persistent diplopia and correcting significant enophthalmos suggests that, when executed proficiently by surgeons experienced in the respective techniques, satisfactory functional and volumetric restoration of the orbit can be achieved irrespective of the specific access route. Diplopia following orbital floor fractures has a multifactorial etiology. It can result from direct entrapment of extraocular muscles (most commonly the inferior rectus or inferior oblique) or surrounding connective tissues within the fracture site, leading to mechanical restriction of globe motility. It can also arise from direct contusion or ischemic injury to the muscle fibers, neural damage to the motor nerves supplying these muscles (branches of the oculomotor nerve), periorbital edema causing temporary muscle dysfunction, or significant changes in orbital volume affecting the functional length and vector of the extraocular muscles. Enophthalmos, the posterior sinking of the globe, is primarily a consequence of orbital volume expansion due to the herniation of orbital fat and sometimes muscle tissue through the bony defect into the maxillary sinus, and less commonly due to post-traumatic fat atrophy or cicatricial contraction of orbital contents. The success of surgical repair in addressing these issues hinges on several critical factors: timely intervention (particularly for muscle entrapment), complete release of any entrapped tissues, accurate anatomical reconstruction of the orbital floor defect to restore normal orbital volume and contour, and the stable placement of an appropriately sized and shaped implant material to bridge the defect and support the orbital contents. The findings of this meta-analysis imply that each of the evaluated approaches can provide adequate visualization and access for surgeons to perform these critical maneuvers effectively. For instance, while the transconjunctival approach might offer slightly more limited anterior exposure for some, it can be readily extended or combined with endoscopic assistance to manage larger or more posterior defects. Similarly, endoscopic approaches, particularly transantral, offer superb visualization of the posterior shelf of the orbit, which is crucial for correct implant placement to prevent residual enophthalmos, but may be more challenging

for managing the most anterior part of some fractures compared to direct transcutaneous visualization. The key factor appears to be the ability to achieve the surgical goals, rather than the specific portal of entry itself.[15,16]

The observation that endoscopic approaches, and particularly the subciliary approach, when compared to endoscopic, were associated with varying risks of infraorbital nerve (ION) hypoesthesia warrants discussion. The ION, after branching from the maxillary nerve in the pterygopalatine fossa, enters the orbit through the inferior orbital fissure, traverses the infraorbital groove and then the infraorbital canal within the orbital floor, and finally exits onto the face through the infraorbital foramen. Its pathway makes it particularly vulnerable during orbital floor fracture and repair. Injury can occur directly from the fracture fragments, from stretching or compression due to herniated orbital tissues, or iatrogenically during surgical manipulation. The subciliary approach, requiring dissection across the anterior face of the maxilla and along the inferior orbital rim, places the ION and its terminal branches at risk, particularly if the dissection extends too medially or inferiorly near the infraorbital foramen, or if excessive retraction is applied. The transconjunctival approach may involve less direct manipulation over the nerve's exit point, but dissection along the orbital floor still carries a risk, especially if the nerve is dehiscent within its groove or if fracture lines involve the canal. Endoscopic approaches, especially the transantral technique, access the orbital floor from its inferior (sinus) aspect. This may theoretically reduce direct trauma to the main trunk of the ION as it courses within the floor, as the dissection and implant placement occur predominantly inferior or directly onto the bony floor containing the nerve. However, aggressive elevation of the periosteum from the sinus side or manipulation of fracture fragments can still lead to nerve contusion or traction. The finding that the subciliary approach had a significantly higher risk of ION hypoesthesia compared to endoscopic techniques in this analysis (OR 1.72) and that combined transcutaneous approaches also showed a higher risk (OR 1.60 vs. endoscopic) suggests that the directness of dissection over the nerve's typical anatomical course with external incisions might contribute to a higher incidence of sensory disturbance. This is an area where the minimally invasive nature of endoscopic surgery, by potentially minimizing direct nerve handling, could offer a tangible benefit, as also suggested by the user-provided document.[17,18]

The rates of entropion and postoperative infection were found to be low and not significantly different between the approaches. Entropion is less common than ectropion and is typically caused by scarring of the posterior lamella (conjunctiva and tarsus) or spasm/overaction of the preseptal orbicularis muscle. The low rates suggest that careful tissue handling generally prevents this complication across all approaches. Similarly, low infection rates, despite the orbit's proximity to the paranasal sinuses (which are not sterile environments), attest to the robust vascular supply of the periorbital tissues and the common use of prophylactic antibiotics, though the evidence for routine antibiotic use in uncomplicated orbital fractures is itself a subject of debate. The choice of implant material, while not a focus of this approach-comparison meta-analysis, can also influence infection risk, with some materials potentially being more prone to biofilm formation than others. The user-provided document mentions various implant materials, including autografts, allografts, and alloplastics like titanium and polyethylene, each with its own characteristics regarding biocompatibility and infection resistance.[19,20]

It is important to frame these findings within the broader context of surgical practice. The choice of surgical approach is often influenced by surgeon's training, experience, and comfort level with a particular technique. Complex fracture patterns, such as those extending significantly posteriorly or involving multiple orbital walls, may necessitate combined approaches or specific techniques that offer optimal visualization and instrumentation for that particular injury. For example, a surgeon might

choose an endoscopic-assisted transconjunctival approach for a large posterior floor fracture to combine the cosmetic benefits of the transconjunctival incision with the enhanced posterior visualization afforded by the endoscope. Patient factors, including previous ocular surgery, skin type, and specific concerns about scarring or potential complications, also play a crucial role in shared decision-making.

The slightly higher technical demand and steeper learning curve associated with transconjunctival and particularly endoscopic approaches, as mentioned in the user-provided text, are practical considerations. However, as surgical training evolves and experience with these techniques grows, their adoption is likely to increase, especially if they continue to demonstrate benefits in terms of reduced morbidity for specific outcomes like eyelid malposition or nerve injury. The discussion on the timing of surgery, also raised in the user's document, while not directly compared in this meta-analysis of approaches, remains a critical variable influencing final outcomes regardless of the chosen technique. Early surgery (within 1-2 weeks) is generally advocated for significant entrapment or large defects to prevent irreversible muscle fibrosis or enophthalmos, but delaying surgery slightly can allow for edema to resolve, potentially facilitating dissection. In summary, this meta-analysis provides synthesized evidence suggesting that while functional restoration of the orbit can be achieved effectively through multiple surgical corridors, the transconjunctival approach offers a distinct advantage in minimizing the risk of postoperative ectropion. Endoscopic techniques show promise in reducing infraorbital nerve morbidity. These findings, integrated with an understanding of the underlying anatomy and pathophysiology of orbital trauma and its surgical repair, should aid clinicians in making more informed, individualized choices for their patients, always balancing the goals of functional restoration with the minimization of iatrogenic complications.

4. Conclusion

This meta-analysis, through a quantitative synthesis of data from seven comparative studies, provides valuable insights into the relative merits of transconjunctival, subciliary, and endoscopic surgical approaches for the repair of orbital floor fractures. The most salient finding was the statistically significant and clinically meaningful reduction in the incidence of postoperative ectropion when employing the transconjunctival approach as compared to the subciliary technique. This underscores a distinct cosmetic and functional eyelid advantage for the transconjunctival route. Importantly, all three evaluated surgical modalities—transconjunctival, subciliary, and endoscopic—demonstrated comparable efficacy in achieving the primary therapeutic goals of resolving persistent postoperative diplopia and correcting or preventing significant enophthalmos. This suggests that, in experienced hands, the fundamental objectives of orbital floor reconstruction can be successfully met irrespective of the specific access pathway chosen, provided that sound surgical principles of tissue release, volumetric restoration, and stable reconstruction are adhered to. Furthermore, the analysis indicated that endoscopic approaches might be associated with a lower incidence of postoperative infraorbital nerve hypoesthesia when compared to transcutaneous methods, particularly the subciliary approach. Rates of other complications, such as entropion and surgical site infection, were found to be low and did not differ significantly among the three techniques. The selection of the optimal surgical approach for any given patient with an orbital floor fracture remains a nuanced decision.

5. References

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