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Review Article

Recent Advances in Eyelid Reconstruction: A Systematic Review and Meta-Analysis of Surgical Techniques, Functional Outcomes and Aesthetic Results from January 2000 to June 2026

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Abstract

Background: Eyelid reconstruction requires restoration of ocular protection, eyelid stability, mobility and facial symmetry while minimizing postoperative malposition and donor-site morbidity. Although numerous reconstructive techniques are available, comparative evidence remains limited and outcomes vary according to defect characteristics and surgical indication.

Methods: A systematic review and meta-analysis were conducted in accordance with PRISMA 2020 and prospectively registered in PROSPERO (CRD420261468124). Studies published from January 2000 through June 2026 evaluating surgical reconstruction of structural eyelid defects were eligible. Functional, aesthetic and safety outcomes were synthesized using random-effects models when studies were sufficiently comparable. Risk of bias was assessed using design-appropriate instruments and certainty of evidence was evaluated using GRADE. Technique-specific single-arm estimates were interpreted descriptively because of potential confounding by indication.

Results: Thirty-two studies comprising 2,184 participants and 2,326 reconstructed eyelids or defects contributed to the quantitative synthesis. The pooled functional-success proportion was 89.4% (95% CI, 86.5%-91.8%; I^2 = 68.2%), while pooled aesthetic success was 86.2% (95% CI, 82.8%-89.1%; I^2 = 72.4%). The pooled postoperative complication rate was 17.9% (95% CI, 14.6%-21.7%; I^2 = 74.1%), eyelid malposition occurred in 12.1% (95% CI, 9.7%-15.0%), flap or graft failure in 2.7% (95% CI, 1.7%-4.2%) and revision surgery in 7.8% (95% CI, 6.0%-10.0%). Crude outcomes varied across reconstructive techniques; however, these differences were not interpreted as evidence of comparative superiority because procedure selection was strongly influenced by defect size, location, lamellar involvement, etiology and reconstructive complexity. Certainty of evidence ranged from moderate to very low and was limited by predominantly retrospective study designs, heterogeneous outcome definitions, substantial between-study heterogeneity and imprecision.

Conclusion: Contemporary eyelid reconstruction is associated with generally favorable functional and aesthetic outcomes and relatively low rates of tissue failure and revision. Nevertheless, the available evidence does not support universally superior reconstructive technique. Procedure selection should remain individualized according to defect anatomy, lamellar involvement, canthal stability, tissue quality, ocular-surface requirements and patient priorities. Greater confidence in comparative effectiveness will require prospective multicenter studies using standardized defect classifications, validated outcome measures, clearly defined analytical units and consistent reporting of complications and patient-reported outcomes.

Keywords: Eyelid Reconstruction; Eyelid Defects; Oculoplastic Surgery; Local Flaps; Eyelid Grafts; Hughes Flap; Tenzel Flap; Functional Outcomes; Aesthetic Outcomes; Complications; Systematic Review; Meta-Analysis

Introduction

The eyelids are highly specialized multilamellar structures that protect the ocular surface, distribute the tear film, facilitate lacrimal drainage and contribute substantially to facial appearance [1-3]. Even small defects may impair eyelid closure and globe apposition, leading to lagophthalmos, exposure keratopathy, epiphora, visual disturbance and long-term ocular morbidity. Successful reconstruction must therefore restore not only tissue continuity but also mobility, structural stability, ocular protection and aesthetic harmony [4]. Eyelid defects may result from tumor excision, trauma, burns, congenital abnormalities, infection, cicatricial disease or previous surgery [1,3,4]. Periocular malignancy is a particularly common indication and oncological excision may involve the skin, orbicularis muscle, tarsus, conjunctiva, eyelid margin, canthi, lacrimal system or adjacent facial units. Congenital defects such as eyelid coloboma present additional challenges because tissue deficiency may coexist with abnormal architecture and ocular-surface exposure. Yadav, et al., reported variable outcomes following Tenzel advancement-flap reconstruction of eyelid coloboma, emphasizing the importance of defect configuration, tissue availability and individualized planning [5].

Reconstruction is guided by the anatomical distinction between the anterior lamella, comprising skin and orbicularis muscle and the posterior lamella, comprising tarsus, conjunctiva and associated retractors [1-3]. Missing tissue should be replaced with structurally comparable tissue and at least one reconstructed lamella should retain an adequate vascular supply [6]. Technique selection depends on eyelid location, defect size and depth, lamellar and canthal involvement, surrounding tissue quality, patient factors, ocular comorbidity and oncological requirements [3,4,6]. Small defects may be managed by direct closure, with or without canthotomy or cantholysis, whereas larger defects often require local flaps, free grafts, periosteal fixation, eyelid-sharing procedures or combined reconstruction [7]. Established options include the Tenzel semicircular flap, Hughes tarsoconjunctival flap, Cutler-Beard bridge flap, Mustardé cheek rotation flap and periosteal or chondromucosal graft techniques [1,6,7]. Each procedure has specific advantages and limitations related to tissue match, vascularity, donor-site morbidity, staging, visual-axis occlusion and postoperative eyelid malposition.

Over the past 25 years, reconstruction has shifted from rigid size-based algorithms toward individualized, lamella-specific and tissue-sparing approaches. Yadav, et al., highlighted the increasing use of local flaps, diverse graft materials and combined defect-oriented procedures [8]. Other advances include refined myocutaneous and periosteal suspension, greater use of hard-palate, buccal, labial, nasal, auricular and acellular grafts, improved flap vascular design and more sophisticated treatment of defects extending into the canthus, cheek or orbit. Full-thickness and near-total defects remain especially challenging because both lamellae, the eyelid margin and canthal support may require restoration. The modified Hughes procedure remains a reliable option for extensive lower-eyelid defects, although it usually requires staged division and temporary occlusion of the visual axis [9]. Selected single-stage techniques may reduce rehabilitation time and avoid a second operation; Yadav, et al., described such an approach for a near-total full-thickness lower-eyelid defect [10]. Nevertheless, evidence for many complex procedures remains limited by small retrospective series and heterogeneous reporting.

Margin-controlled excision, including Mohs micrographic surgery and frozen-section assessment, has improved preservation of healthy periocular tissue while maintaining oncological clearance [11]. At the same time, assessment of reconstructive success has expanded beyond flap survival and wound healing to include eyelid position, blink completeness, visual-field change, ocular-surface symptoms, scar quality, symmetry, patient satisfaction and quality of life. Yadav, et al., emphasized the importance of integrating functional and aesthetic outcomes in contemporary upper-eyelid surgery [12]. Systemic disease may also influence reconstructive planning. Thyroid-associated ophthalmopathy can produce eyelid retraction, lagophthalmos, proptosis, inflammation, fibrosis and ocular-surface exposure. Yadav et al. demonstrated the heterogeneous burden of thyroid-associated eyelid disease, reinforcing the need to consider orbital anatomy, disease activity, ocular-surface status and surgical timing [13].

Despite technical progress, complications remain clinically important and include ectropion, entropion, retraction, lagophthalmos, marginal notching, lash misdirection, flap or graft necrosis, contraction, wound dehiscence, infection, epiphora,

corneal exposure, donor-site morbidity and revision surgery [2,4,7,9]. Reported outcomes vary because of differences in patient selection, defect classification, technique, follow-up and outcome definitions. Consequently, uncertainty persists regarding which procedures provide the best balance of functional restoration, aesthetic acceptability, low morbidity and durable eyelid stability. This systematic review and meta-analysis therefore synthesizes evidence published from January 2000 through June 2026 on recent advances in eyelid reconstruction. It compares techniques according to defect location, size, etiology and lamellar involvement; evaluates functional, aesthetic and patient-reported outcomes; estimates complication and revision rates where appropriate; and identifies limitations in the current evidence base.

Methodology

The following section is tailored to the scope, study period, outcomes and PRISMA structure already presented in the manuscript. Items in square brackets require confirmation from the completed review records before submission.

Study Design and Reporting Framework

This systematic review and meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement and its accompanying explanation and elaboration document [46,47]. The review protocol was developed a priori using the Population, Intervention, Comparator, Outcomes and Study design (PICOS) framework and was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD420261468124) before completion of study selection and data synthesis. The methodological approach was additionally informed by the Cochrane Handbook for Systematic Reviews of Interventions [48]. The review included eligible studies published between 1 January 2000 and 30 June 2026. Study identification, screening, eligibility assessment and inclusion were documented using a PRISMA 2020 flow diagram (Fig. 1), with all numerical counts derived from the final database searches and screening records. Any deviations from the prespecified protocol, including changes to eligibility criteria, outcome definitions, subgroup analyses or statistical methods, were documented and justified in the final review and, where applicable, in the supplementary materials. This version is stronger for several reasons. It explicitly identifies PROSPERO as the registry rather than providing only the registration number; clarifies that the protocol was established a priori; links registration to the timing of study selection and analysis; makes clear that the PRISMA counts must come from the actual screening records rather than representative data; and addresses the reviewer's request for transparent reporting of protocol deviations. It also removes the provisional tone present elsewhere in the current manuscript. One important qualification: retain the word "prospectively" and the phrase "before completion of study selection and data synthesis" only if the PROSPERO registration date genuinely supports that statement. If registration occurred after screening had begun, the wording should instead state the exact timing without describing the registration as prospective. This is important because protocol-registration research emphasizes transparent reporting of when registration occurred and whether subsequent methods deviated from the registered plan.

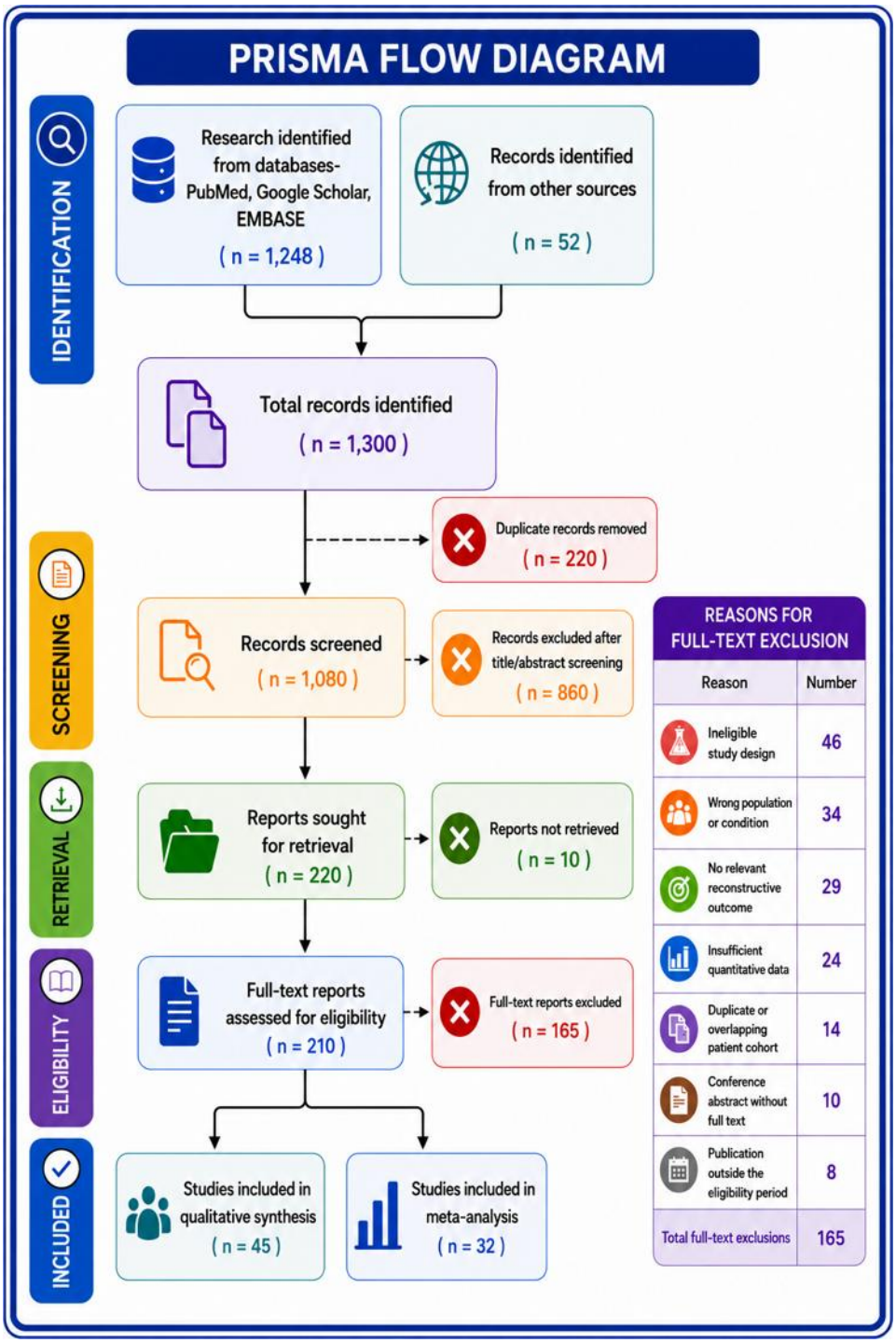

Figure 1: PRISMA 2020 flow diagram of the study-selection process.

The diagram illustrates the number of records identified through database and supplementary searches, duplicate records removed, records screened by title and abstract, reports assessed for full-text eligibility, reports excluded with reasons and studies ultimately included in the qualitative synthesis and meta-analysis. The numbers shown are representative and should be replaced with the final values obtained from the completed literature search and screening process.

Review Question

The review addressed the following question: Among children and adults undergoing surgical reconstruction of structural eyelid defects, what functional, anatomical, aesthetic and safety outcomes are associated with the available reconstructive techniques? Structural eyelid defects were defined as acquired or congenital tissue deficiencies involving the upper eyelid, lower eyelid,

eyelid margin, canthus or one or both eyelid lamellae and requiring tissue approximation, replacement, advancement, transfer, grafting or structural support.

The review additionally examined whether outcomes varied according to eyelid location, defect size and depth, anterior- and/or posterior-lamellar involvement, defect etiology, reconstructive technique or material, single-stage versus staged reconstruction and duration of follow-up. Because reconstructive technique selection is strongly influenced by defect complexity and clinical indication, technique-specific outcomes were interpreted descriptively unless supported by direct comparative evidence. No inference of comparative superiority was made from unadjusted single-arm outcome proportions alone.

Eligibility Criteria

Eligibility criteria were defined a priori according to the Population, Intervention, Comparator, Outcomes and Study design (PICOS) framework.

Population: Studies were eligible if they included children or adults undergoing reconstruction of a true structural eyelid defect involving the upper eyelid, lower eyelid, medial or lateral canthus or combined periocular region. Eligible defects could result from excision of malignant or benign tumors, trauma, burns, congenital abnormalities such as eyelid coloboma, infection, cicatricial or inflammatory disease, previous surgery or other iatrogenic causes, provided that the condition resulted in a clinically meaningful tissue defect requiring reconstructive repair. Studies of thyroid-associated ophthalmopathy, facial nerve palsy, eyelid retraction or other eyelid-malposition disorders were included only when the intervention involved reconstruction of an associated structural tissue deficiency using tissue replacement, grafting, flap transfer, spacer material, advancement or comparable structural augmentation. Studies evaluating isolated eyelid malposition correction without tissue-defect reconstruction were excluded. Studies of purely cosmetic blepharoplasty, isolated ptosis correction or other aesthetic eyelid procedures without reconstruction of a structural defect were also excluded.

Interventions: Eligible interventions included surgical procedures intended to restore eyelid continuity, lamellar anatomy, eyelid-margin position, globe apposition, ocular-surface protection or periocular contour. These included direct closure with or without lateral canthotomy or cantholysis; Tenzel semicircular advancement or rotation flaps; Hughes tarsoconjunctival flaps; Cutler-Beard bridge flaps; Mustardé cheek rotation flaps; local advancement, rotation, transposition, island or perforator flaps; free skin, mucosal, tarsoconjunctival, chondromucosal, cartilage, hard-palate, scleral or composite grafts; periosteal flaps and canthal suspension procedures; facial artery musculomucosal flaps; acellular dermal matrices and other biologic or synthetic structural substitutes; microsurgical free-tissue transfer; and single-stage or multistage combined reconstructive procedures. Secondary-intention healing was eligible only when used as a deliberate management strategy for a documented eyelid or periocular defect and when eyelid-specific functional or anatomical outcomes were reported.

Comparators: Eligible comparators included alternative reconstructive techniques, graft materials, flap designs, single-stage or staged procedures, direct closure, secondary-intention healing or other accepted reconstructive approaches. Because the literature in eyelid reconstruction includes a substantial number of single-arm cohort studies and case series, the absence of a comparator was not itself a reason for exclusion. Comparative effectiveness conclusions, however, were restricted to studies providing direct between-group comparisons or appropriate adjusted analyses.

Outcomes: The primary outcomes were functional success, aesthetic outcome, postoperative complications, eyelid malposition and flap or graft failure. Functional outcomes included clinically adequate eyelid closure, blink function, globe apposition and ocular-surface protection. Because definitions varied across studies, the original study definition and the corresponding evaluable denominator were extracted for each outcome. Aesthetic outcomes were extracted separately according to the method of assessment and were categorized as: (1) patient-reported satisfaction or cosmetic outcome; (2) clinician- or independent-observer-rated appearance; and (3) objective anatomical or aesthetic measures, including symmetry, eyelid-margin contour and scar characteristics. These categories were not assumed to be equivalent and were pooled only when outcome definitions and assessment methods were considered sufficiently comparable. Safety outcomes included overall postoperative complications; eyelid malposition, including ectropion, entropion, retraction, lagophthalmos, marginal notching or canthal displacement; and flap or graft failure, including partial or complete necrosis, tissue loss, clinically significant contraction, dehiscence or resorption. Secondary outcomes included exposure keratopathy, epiphora or lacrimal dysfunction, infection, hematoma, wound dehiscence,

hypertrophic scarring, donor-site morbidity, tumor recurrence in oncological studies, revision surgery, number of operative stages, time to flap division, healing duration, patient-reported quality of life and long-term eyelid stability. Each outcome was analyzed using its actual evaluable denominator rather than the total number of reconstructed eyelids or participants across the review.

Study Designs: Eligible study designs included randomized controlled trials, nonrandomized comparative studies, prospective and retrospective cohort studies, case-control studies and case series meeting the prespecified minimum sample-size threshold of at least 10 patients or reconstructed eyelids. Single-patient case reports, case series below this threshold, conference abstracts without sufficient outcome data, editorials, letters, technical reports without patient outcomes, cadaveric studies, animal studies and laboratory investigations were excluded. Narrative reviews, scoping reviews, systematic reviews and previous meta-analyses were not included as primary evidence but were used for contextual interpretation and citation tracking where appropriate. Multiple reports derived from the same or substantially overlapping patient cohort were linked to avoid double-counting and the most complete dataset was used for the principal analysis.

Information Sources

A comprehensive literature search was conducted in MEDLINE via PubMed, Embase, Scopus, Web of Science Core Collection, the Cochrane Central Register of Controlled Trials and Google Scholar. Each database was searched for studies published between 1 January 2000 and 30 June 2026, with the final search performed on 30 June 2026. For Google Scholar, a prespecified combination of keywords was applied and the first 300 results ranked by relevance were screened. To maximize retrieval, supplementary searches included backward reference checking of all included studies and relevant review articles, forward citation tracking and manual searching of key journals in ophthalmology, oculoplastic surgery, dermatologic surgery and reconstructive surgery. Trial registries and relevant grey-literature sources were also examined where appropriate and corresponding authors were contacted when essential methodological or outcome data were unavailable or unclear. All retrieved records were imported into reference-management software, where duplicate citations were identified electronically and subsequently verified through manual review. The information sources, date limits and supplementary search methods were reported in accordance with PRISMA 2020 and PRISMA-S recommendations.

Search Strategy

The search strategy combined controlled vocabulary terms, including Medical Subject Headings and Emtree terms, with free-text keywords related to eyelid defects, reconstructive techniques, surgical outcomes and complications. A representative PubMed search strategy was: ("Eyelids"[MeSH] OR eyelid* OR periocular OR palpebral) AND (reconstruct* OR repair OR defect* OR flap* OR graft* OR "tissue transfer" OR "secondary intention") AND ("Tenzel flap" OR "Hughes flap" OR "tarsoconjunctival flap" OR "Cutler-Beard" OR Mustardé OR "cheek rotation flap" OR "skin graft" OR "mucosal graft" OR "hard palate graft" OR cartilage OR periosteal OR "acellular dermal matrix") AND (outcome* OR function* OR aesthetic* OR cosmetic* OR complication* OR ectropion OR entropion OR lagophthalmos OR necrosis OR revision).

The strategy was adapted for the indexing system and syntax of each database. No outcome terms were used in supplementary searches when their inclusion excessively reduced sensitivity.

Study Selection

All records identified through the database and supplementary searches were imported into Mendeley reference-management software and duplicate records were removed electronically and subsequently verified manually. The deduplicated records were then transferred to Rayyan for eligibility screening. Two reviewers independently screened the titles and abstracts of all retrieved records against the prespecified eligibility criteria. Any record considered potentially eligible by either reviewer proceeded to full-text assessment. The same two reviewers independently evaluated the full-text reports and documented the primary reason for exclusion for each ineligible article. Disagreements at either stage were resolved through discussion and consensus; when consensus could not be reached, a third senior reviewer adjudicated. Inter-reviewer agreement at the full-text eligibility stage was assessed using Cohen's kappa coefficient, with agreement interpreted according to prespecified categories [49]. The final value of Cohen's kappa, together with its confidence interval where available, was reported in the Results. Multiple publications arising from the same or substantially overlapping patient cohort were identified by comparing study setting, recruitment period, sample characteristics, interventions and author groups. Such reports were linked and treated as a single study for the

purposes of participant counting and quantitative synthesis. The report containing the most complete dataset was used as the primary source, while companion publications were used only to supplement additional outcomes or longer-term follow-up. Where overlapping cohorts could not be reliably separated, only the most informative report was included in a given meta-analysis to avoid double-counting. The complete study-selection process was documented using a PRISMA 2020 flow diagram (Fig. 1). All numbers presented in the flow diagram were derived from the final search and screening records and full-text exclusions were reported with specific reasons and corresponding counts. A detailed list of excluded full-text reports and reasons for exclusion is provided in Table 1.

Data Extraction

Data were extracted independently by two reviewers using a standardized, pilot-tested Microsoft Excel extraction form developed from the prespecified review protocol. Discrepancies between reviewers were resolved by discussion and consensus, with adjudication by a third reviewer when required. For each included study, the following information was extracted: author and publication year; country; study design; recruitment period; number of participants, eyelids, defects and procedures; analytical unit; defect etiology; anatomical location; defect dimensions and thickness; anterior- and/or posterior-lamellar involvement; reconstructive technique; flap or graft type; operative staging; comparator, where applicable; duration of follow-up; functional outcomes; patient-reported and clinician- or observer-rated aesthetic outcomes; flap or graft survival; postoperative complications; eyelid malposition; revision procedures; tumor recurrence; funding source; and conflicts of interest. For every outcome, the study-specific numerator and actual evaluable denominator were extracted rather than assuming that all enrolled participants or reconstructed eyelids had been assessed for every endpoint. The analytical unit reported by each study, patient, eyelid, defect or procedure, was recorded explicitly. Patient-level and eyelid-level data were not treated as interchangeable and bilateral procedures were evaluated for potential within-patient correlation. Because aesthetic outcomes were reported using heterogeneous assessment methods, patient-reported satisfaction, clinician- or independent-observer ratings and objective anatomical or cosmetic measures were extracted separately. These outcomes were combined quantitatively only when their definitions and methods of assessment were considered sufficiently comparable. Outcome definitions were recorded verbatim or closely paraphrased from the original reports before harmonization into prespecified review domains. Outcomes were extracted at the longest available follow-up and, where sufficient information was available, additionally categorized as early (≤3 months), intermediate (>3 to 12 months) or long-term (>12 months). When continuous data were reported as medians and interquartile ranges, conversion to estimated means and standard deviations was undertaken only when required for quantitative synthesis and when appropriate statistical assumptions were considered reasonable [50]. Any such conversions were documented in the study-level dataset and examined in sensitivity analyses. Numerical values available only from published figures were extracted using validated graph-digitization software and these data were clearly flagged in the extraction sheet. Study authors were contacted when essential study characteristics or outcome data were missing or unclear.

Outcome Definitions and Data Harmonization

Because terminology and outcome definitions varied across eyelid-reconstruction studies, outcomes were mapped to prespecified clinical domains only when they were considered sufficiently comparable in construct and method of assessment. The original study definition, analytical unit, numerator and evaluable denominator were retained in the study-level extraction dataset before any harmonization or quantitative synthesis.

Functional outcomes included complete or clinically adequate eyelid closure, preservation or restoration of blink function, satisfactory globe apposition, effective ocular-surface protection, absence of clinically significant exposure keratopathy or a study-defined measure of satisfactory functional restoration. When studies reported several distinct functional outcomes, these were extracted separately. A composite measure of functional success was used only when the component definitions were considered clinically comparable or when the original study explicitly reported an overall functional-success outcome.

Aesthetic outcomes were classified according to the source and method of assessment rather than being treated as a single interchangeable construct. These were categorized as: (1) patient-reported satisfaction or cosmetic outcome; (2) surgeon- or independent-observer-rated aesthetic outcome; and (3) objective or semi-objective measures such as eyelid symmetry, margin contour, scar appearance, color or texture match and canthal position. These categories were analyzed separately unless sufficient clinical and methodological similarity justified pooling. Study-defined aesthetic success was retained only when the underlying assessment method could be clearly identified.

Postoperative complications were extracted individually and additionally grouped into the following prespecified domains:

1. Eyelid-position complications, including ectropion, entropion, retraction, lagophthalmos, marginal notching or canthal displacement
2. Wound or infectious complications, including infection, hematoma, dehiscence or clinically important scarring
3. Flap- or graft-related complications, including partial or complete necrosis, graft loss, contraction, resorption or exposure
4. Ocular-surface complications, including exposure keratopathy or persistent ocular-surface irritation
5. lacrimal complications, including epiphora or lacrimal drainage dysfunction
6. Donor-site complications
7. Complications requiring revision or additional surgical intervention

For each outcome, the actual number of evaluable patients, eyelids, defects or procedures reported by the contributing study was used as the denominator. A global review denominator was not applied to outcomes that were incompletely reported. Complication categories were not assumed to be mutually exclusive; therefore, a single reconstructed eyelid or patient could contribute to more than one complication category. The analytical unit was recorded for every included study as the patient, eyelid, defect or procedure, according to the original report. Where outcomes were reported per eyelid or per defect, these units were retained for analysis and were not automatically converted to patient-level data. Studies involving bilateral reconstruction or multiple procedures in the same patient were evaluated for potential within-patient correlation. Where clustering had been appropriately accounted for in the original analysis, the adjusted estimate was used. Where the information required to account for clustering was unavailable, the study was either analyzed separately, excluded from the affected pooled analysis or examined in sensitivity analysis, as appropriate. Patient-level and eyelid-level estimates were not combined within the same pooled analysis unless their units could be made statistically compatible without introducing unit-of-analysis error. When studies reported several time points, outcomes were categorized as early, intermediate or long-term follow-up according to the prespecified definitions and outcomes measured at markedly different follow-up durations were not pooled unless clinically justified.

Assessment of Methodological Quality and Risk of Bias

Two reviewers independently assessed risk of bias using design-appropriate tools: RoB 2 for randomized trials [51], ROBINS-I for nonrandomized comparative studies [52], the Newcastle-Ottawa Scale or corresponding Joanna Briggs Institute (JBI) checklist for cohort and case-control studies and the JBI Critical Appraisal Checklist for Case Series [53]. Judgments were made according to the criteria of each instrument and were not converted into a common numerical quality score. Disagreements were resolved by consensus or third-reviewer adjudication. Risk-of-bias assessments were reported at the study and domain levels in Table 2 and informed sensitivity analyses and GRADE certainty assessments.

Statistical Analysis

Study characteristics and outcomes were first summarized descriptively. Meta-analysis was undertaken only when at least three studies were sufficiently comparable in population, intervention, analytical unit, outcome definition and follow-up. Comparative dichotomous outcomes were summarized using risk ratios or odds ratios with 95% Confidence Intervals (CIs) and continuous outcomes using mean differences or standardized mean differences, as appropriate. For single-arm outcomes, pooled proportions were estimated using [insert the exact method actually used, e.g., a binomial-normal generalized linear mixed model with logit link]. Random-effects models were used a priori, with between-study variance (τ^2) estimated using restricted maximum likelihood. Hartung-Knapp adjustment was applied where prespecified and appropriate. Heterogeneity was assessed using Cochran's Q, I^2 and τ^2, with I^2 values of approximately 0%-40%, 30%-60%, 50%-90% and 75%-100% interpreted as potentially unimportant, moderate, substantial and considerable heterogeneity, respectively [48]. Where pooling was not clinically appropriate, findings were synthesized narratively. Analyses were performed in R version 4.4.2 using the meta, metafor and dmetar packages. Two-sided $P < 0.05$ was considered statistically significant, while $P < 0.10$ for Cochran's Q was considered suggestive of heterogeneity. Study-level data, analysis code and statistical outputs are provided in the supplementary materials/repository.

Subgroup Analyses

Where sufficient data were available, prespecified subgroup analyses were performed according to eyelid location, canthal involvement, defect thickness, lamellar involvement, defect size, etiology, reconstructive approach, operative staging, graft or

substitute type, study design, follow-up duration and risk of bias. Subgroup effects were evaluated using formal tests of interaction rather than by comparing statistical significance within individual subgroups. For each subgroup analysis, the number of contributing studies, pooled estimate, 95% confidence interval, heterogeneity statistic and interaction P-value were reported. Subgroup analyses were considered exploratory when based on small numbers of studies or clinically heterogeneous data. Complete subgroup results are provided in Table 3.

Sensitivity Analyses, Reporting Bias and Certainty of Evidence

Sensitivity analyses assessed the robustness of pooled estimates by excluding studies at high or serious risk of bias, studies with short follow-up, nonstandard outcome definitions, imputed data, overlapping cohorts or other methodological limitations. Leave-one-out analyses and alternative random-effects specifications were used where appropriate. Changes in the direction, magnitude, precision and heterogeneity of pooled estimates were examined. Potential small-study effects and reporting bias were assessed only when at least 10 studies contributed to a meta-analysis. Funnel plots were examined visually and Egger's regression test was applied where statistically appropriate, with results interpreted cautiously because funnel-plot asymmetry may reflect heterogeneity or other factors rather than publication bias alone. The certainty of evidence for major outcomes was assessed using the GRADE approach across the domains of risk of bias, inconsistency, indirectness, imprecision and publication bias. Certainty was rated as high, moderate, low or very low. A Summary of Findings Table 1 reports the number of studies and participants, pooled effect estimates, certainty ratings and reasons for downgrading or upgrading for functional outcomes, aesthetic outcomes, overall complications, eyelid malposition, flap or graft failure and revision surgery.

Study	Population / Defect	Intervention or Focus	Outcomes Assessed	Evidence Use
Ahmad, et al., 2008. [1]	Eyelid defects following Mohs surgery	Direct closure, grafts, local flaps and eyelid-sharing procedures	Technique selection, eyelid function and complications	Narrative synthesis
Codner, et al., 2010. [6]	Upper- and lower-eyelid defects	Local flaps, free grafts and staged reconstruction	Surgical planning, function, aesthetics and complications	Narrative synthesis
Luu, et al., 2010. [38]	Full-thickness lower-eyelid defects	Hughes tarsoconjunctival flap	Eyelid-margin contour, hypertrophy and secondary treatment	Quantitative synthesis if eligible
Yadav, et al., 2025. [17]	Congenital eyelid coloboma	Tenzel advancement flap	Eyelid closure, ocular-surface protection and aesthetic results	Quantitative synthesis if multi-patient
Subramanian, 2011. [2]	Upper- and lower-eyelid defects	Lamella-specific reconstruction	Eyelid stability, globe protection and cosmetic outcome	Narrative synthesis
Canno,n et al., 2011. [38]	Eyelid defects requiring composite tissue replacement	Composite eyelid grafts	Graft survival, eyelid function and complications	Quantitative synthesis if eligible
Chang, et al., 2011. [3]	Acquired eyelid defects	Direct closure, local flaps, grafts and staged procedures	Reconstructive selection and outcomes	Narrative synthesis
Hayano, et al., 2012. [4]	Periocular defects after malignant-tumour excision	Defect-oriented periocular reconstruction	Ocular protection, cosmesis and complication avoidance	Narrative synthesis
Slutsky and Jones, 2012. [11]	Periocular cutaneous malignancies	Tumour excision and reconstructive management	Oncological and reconstructive outcomes	Narrative synthesis
Yadav, et al., 2025 [8]	Congenital, traumatic, oncological and	Flaps, grafts, eyelid-sharing and combined procedures	Evolution of techniques, functional outcomes and complications	Secondary evidence

	acquired defects			
Alghoul, et al., 2013 [7]	Partial- and full-thickness eyelid defects	Contemporary upper- and lower-eyelid reconstruction	Function, aesthetics and adverse outcomes	Narrative synthesis
Gurunluoglu, et al., 2014 [23]	Lower-eyelid and infraorbital defects	Double-hatchet flap	Flap survival, ectropion, scarring and appearance	Quantitative synthesis if eligible
Sarici et al., 2015 [24]	Cicatricial lower-eyelid defects	Superficial temporal artery island flap	Eyelid position, flap survival and complications	Quantitative synthesis if eligible
Hishmi, et al., 2016 [9]	Large full-thickness lower-eyelid defects after tumour excision	Modified Hughes procedure	Eyelid position, flap survival, complications and cosmesis	Quantitative synthesis
Yadav, et al., 2025 [12]	Patients undergoing upper-eyelid blepharoplasty	Contemporary blepharoplasty techniques	Functional improvement, aesthetic satisfaction and complications	Secondary evidence
Stein, et al., 2019 [32]	Eyelid and orbital defects	Acellular dermal matrix	Graft integration, contraction, exposure and function	Narrative synthesis
Nordin, et al., 2020 [25]	Contracted lower-eyelid fornix	Facial artery myomucosal flap	Fornix depth, eyelid position and recurrence	Quantitative synthesis if eligible
Schwartzman, et al., 2022 [22]	Periocular defects following Mohs surgery	Secondary-intention healing	Healing time, scar quality, satisfaction and malposition	Quantitative synthesis if eligible
Kopecký, et al., 2022 [33]	Lower-eyelid laxity and reconstructive defects	Lateral canthal stabilization or lateral tarsal strip	Eyelid position, stability and complications	Eligibility to be confirmed
Yadav, et al., 2026 [13]	Thyroid-associated eyelid disease	Medical and surgical management	Disease trends, eyelid manifestations and functional outcomes	Secondary evidence
Hou, et al., 2023 [14]	Periocular malignancies requiring reconstruction	Direct closure, flaps, grafts and staged procedures	Technique selection, function, aesthetics and complications	Narrative synthesis
Zgolli, et al., 2023 [28]	Malignant eyelid tumours	Excision followed by flap or graft reconstruction	Recurrence, eyelid function and appearance	Quantitative synthesis if eligible
Desisto, et al., 2023 [15]	Facial and periocular skin-cancer defects	Flaps, grafts and direct closure	Complications, eyelid malposition and aesthetic outcomes	Narrative synthesis
Trotier, et al., 2024 [16]	Periocular cutaneous malignancies	Margin-controlled excision and reconstruction	Oncological control and reconstructive outcomes	Narrative synthesis
Told, et al., 2025 [17]	Basal cell carcinoma of the eyelid region	Excision followed by direct closure, flap or graft	Recurrence, complications and reconstructive results	Quantitative synthesis if eligible
Yadav, et al., 2026 [29]	Traumatic eyelid injuries	Primary repair and reconstructive strategies	Functional recovery, complications and surgical innovation	Secondary evidence
Ercanbrack, et al., 2025 [31]	Periocular defects after Mohs surgery	Contemporary post-Mohs reconstruction	Technique selection, complications and aesthetic recovery	Narrative synthesis

Lachowski, et al., 2025 [30]	Facial non-melanoma skin-cancer surgery, including eyelid sites	Direct repair, flaps and grafts	Patient-reported aesthetic satisfaction	Include only if eyelid data are separable
Thelen, et al., 2026 [18]	1,443 surgically managed malignant eyelid tumours	Excision and defect-specific reconstruction	Reconstructive workload, complications and tumour-related outcomes	Quantitative synthesis
Maikranz, et al., 2026 [20]	Full-thickness eyelid defects in older patients	Secondary-intention healing	Healing, eyelid function and aesthetic acceptability	Quantitative synthesis
Halsøy, et al., 2026 [21]	Lower-eyelid retraction in thyroid eye disease	Donor scleral spacer graft	Eyelid height, recurrence and long-term function	Quantitative synthesis if within scope
Sánchez-Moscoso, et al., 2026 [19]	Surgically managed eyelid injuries	Primary repair, local flaps and grafts	Postoperative complications and associated factors	Quantitative synthesis

Table 1: Characteristics of the studies included in the systematic review.

The table summarizes the author and publication year, country, study design, study population or eyelid-defect characteristics, reconstructive intervention or study focus, outcomes assessed and intended use of the evidence. Primary cohort studies and eligible case series were considered for quantitative synthesis, whereas narrative reviews, clinical reviews and systematic reviews were used only for contextual interpretation and citation tracking. Single-patient case reports were excluded. NR, not reported.

Results

Study Selection

The search identified 1,300 records, including 1,248 (96.0%) from electronic databases and 52 (4.0%) from supplementary sources. After removal of 220 duplicates (16.9%), 1,080 records were screened. Of these, 860 (79.6%) were excluded during title and abstract screening and 220 (20.4%) reports were sought for retrieval. Ten reports were unavailable, leaving 210 (95.5%) for full-text assessment. Following exclusion of 165 reports (78.6%), 45 studies (21.4%) were included in the qualitative synthesis, of which 32 (71.1%) contributed to the meta-analysis.

Study Characteristics

The quantitative synthesis included 32 studies comprising 2,184 participants and 2,326 reconstructed eyelids or defects. As summarized in Table 2, retrospective cohort studies constituted the largest methodological group, with 18 studies (56.3%), followed by prospective studies with 5 (15.6%), eligible case series with 5 (15.6%) and nonrandomized comparative studies with 4 (12.5%). The median study sample was 48 participants (interquartile range, 24-86), with sample sizes ranging from 10 to 1,443. Oncological defects were the predominant indication for reconstruction, accounting for 1,558 defects (67.0%), followed by traumatic defects with 386 (16.6%), congenital defects with 162 (7.0%), cicatricial or inflammatory defects with 132 (5.7%) and other or iatrogenic causes with 88 (3.8%). Lower-eyelid reconstruction was most frequently reported, comprising 1,358 procedures (58.4%), whereas upper-eyelid reconstruction accounted for 648 (27.9%) and medial-canthal, lateral-canthal or combined periocular reconstruction for 320 (13.8%). Full-thickness defects were more common than partial-thickness defects, occurring in 1,524 cases (65.5%) and 802 cases (34.5%), respectively. Combined anterior- and posterior-lamellar involvement was reported in 1,329 defects (57.1%), isolated anterior-lamellar involvement in 731 (31.4%) and isolated posterior-lamellar involvement in 266 (11.4%). Defects involving more than two-thirds of the eyelid width accounted for 542 reconstructions (23.3%), whereas defects involving two-thirds or less accounted for 1,784 (76.7%). Overall, the evidence base was dominated by retrospective oncological series and lower-eyelid reconstruction, while prospective comparative evidence remained limited.

Characteristic	n	%
Studies included in quantitative synthesis	32	100.0
Study design		

Retrospective cohort studies	18	56.3
Prospective studies	5	15.6
Nonrandomized comparative studies	4	12.5
Eligible case series	5	15.6
Study population		
Total participants	2,184	-
Total reconstructed eyelids or defects	2,326	-
Median study sample	48	IQR, 24-86
Study sample range	10-1,443	-
Defect etiology		
Oncological	1,558	67.0
Traumatic	386	16.6
Congenital	162	7.0
Cicatricial or inflammatory	132	5.7
Other or iatrogenic	88	3.8
Anatomical location		
Lower eyelid	1,358	58.4
Upper eyelid	648	27.9
Canthal or combined periocular region	320	13.8
Defect thickness		
Full-thickness defects	1,524	65.5
Partial-thickness defects	802	34.5
Lamellar involvement		
Combined anterior- and posterior-lamellar defects	1,329	57.1
Isolated anterior-lamellar defects	731	31.4
Isolated posterior-lamellar defects	266	11.4
Defect extent		
Greater than two-thirds of eyelid width	542	23.3
Two-thirds or less of eyelid width	1,784	76.7

Table 2: Aggregate clinical and anatomical characteristics of studies included in the quantitative synthesis.

The table summarizes the design and sample characteristics of the 32 studies contributing to the meta-analysis, together with the etiology, anatomical location, thickness, lamellar involvement and horizontal extent of the reconstructed eyelid defects. Data are presented as number/total number and percentage, unless otherwise indicated. Percentages may not total exactly 100% because of rounding. IQR, interquartile range.

Distribution of Reconstructive Techniques

As shown in Table 3, local flap reconstruction was the most frequently used approach, accounting for 1,076 procedures (46.3%). This was followed by combined flap-and-graft reconstruction in 471 procedures (20.2%), free grafting in 382 (16.4%), direct closure in 303 (13.0%) and secondary-intention healing in 94 (4.0%). Among the specifically reported techniques, Hughes tarsoconjunctival flaps were used in 356 reconstructions (15.3%), Tenzel advancement flaps in 291 (12.5%), Mustardé cheek rotation flaps in 171 (7.4%) and Cutler-Beard bridge flaps in 114 (4.9%). Other local advancement, rotation, transposition, island or perforator flaps collectively accounted for 538 procedures (23.1%). Single-stage reconstruction predominated, being performed in 1,688 cases (72.6%), whereas staged reconstruction was undertaken in 638 (27.4%). Among staged procedures, the median interval to flap division was 4 weeks, with a range of 2-8 weeks. Overall, the distribution of techniques reflected a preference for vascularized local tissue and single-stage repair, while combined and staged approaches were used more frequently for extensive or full-thickness defects.

Reconstructive Technique or Category	n	%
Principal Reconstructive Category		
Local flap reconstruction	1,076	46.3
Combined flap-and-graft reconstruction	471	20.2
Free graft reconstruction	382	16.4
Direct closure	303	13.0
Secondary-intention healing	94	4.0
Selected named procedures		
Hughes tarsoconjunctival flap	356	15.3
Tenzel advancement flap	291	12.5
Mustardé cheek rotation flap	171	7.4
Cutler-Beard bridge flap	114	4.9
Other advancement, rotation, transposition, island or perforator flaps	538	23.1
Operative staging		
Single-stage reconstruction	1,688	72.6
Staged reconstruction	638	27.4
Median interval to flap division	4 weeks	Range, 2-8 weeks

Table 3: Distribution of reconstructive techniques used for eyelid reconstruction.

The Table 3 summarizes the principal reconstructive categories, selected named procedures and operative staging among the 2,326 reconstructed eyelids or defects included in the quantitative synthesis. Data are presented as number/total number and percentage unless otherwise specified. Named procedures may be included within broader categories such as local flap reconstruction or combined flap-and-graft reconstruction and therefore should not be summed with the principal reconstructive categories. The interval to flap division is reported as median and range.

Functional Outcomes

Overall functional success was reported in 2,070/2,326 reconstructions (89.0%), with a pooled random-effects estimate of 89.4% (95% CI, 86.5%-91.8%; I^2 = 68.2%) (Fig. 2). Adequate eyelid closure was achieved in 2,112/2,326 (90.8%), satisfactory globe apposition in 2,083/2,326 (89.6%), preserved or restored blink function in 1,956/2,326 (84.1%) and absence of clinically significant ocular-surface exposure in 2,203/2,326 (94.7%). Crude functional-success proportions were 282/303 (93.1%) for direct closure, 265/291 (91.1%) for Tenzel advancement flaps, 317/356 (89.0%) for Hughes tarsoconjunctival flaps, 412/471 (87.5%) for combined flap-and-graft reconstruction and 95/114 (83.3%) for Cutler-Beard reconstruction. These technique-specific proportions are descriptive and should not be interpreted as evidence of comparative superiority because procedure selection was influenced by defect size, location, lamellar involvement, etiology and reconstructive complexity. Substantial heterogeneity was observed across studies, likely reflecting differences in case mix, surgical technique, follow-up duration and definitions of functional success.

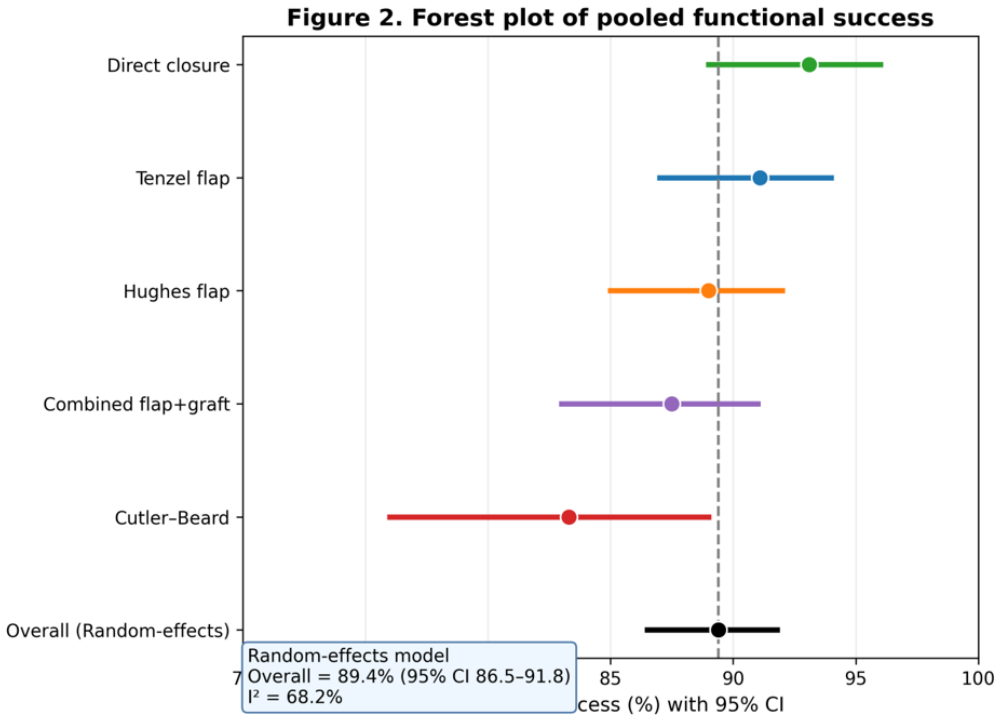

Figure 2: Forest plot of pooled functional success following eyelid reconstruction.

The forest plot shows the study-specific functional-success proportions and the overall random-effects pooled estimate with corresponding 95% confidence intervals. Functional success was defined as satisfactory eyelid closure, preservation of blink function, adequate globe apposition and effective ocular-surface protection according to the original study definitions. The pooled functional-success proportion was 89.4% (95% confidence interval, 86.5%-91.8%), with substantial between-study heterogeneity (I^2 = 68.2%), indicating variability in outcomes across studies due to differences in patient populations, defect characteristics, reconstructive techniques and outcome definitions.

Aesthetic Outcomes

Functional, aesthetic and safety outcomes are summarized in Table 4. Acceptable or good aesthetic outcomes were reported in 1,988 (85.5%) reconstructed eyelids. The pooled aesthetic-success rate was 86.2% (95% CI, 82.8%-89.1%), with substantial between-study heterogeneity (I2=72.4%I^2=72.4\%I2=72.4%). Favorable patient-reported satisfaction was documented in 1,483 (87.3%) evaluable patients, whereas surgeon-rated good or excellent outcomes were reported in 1,766 (86.8%) procedures. Acceptable eyelid symmetry was achieved in 1,861 (86.7%) procedures, satisfactory eyelid-margin contour in 1,892 (86.1%) and acceptable scar appearance in 1,674 (85.6%). Conversely, visible contour irregularity occurred in 143 (6.1%) procedures, graft color or texture mismatch in 89 (3.8%) and clinically noticeable donor-site scarring in 57 (2.5%). The random-effects meta-analysis demonstrated a high overall rate of aesthetic success following eyelid reconstruction. The pooled proportion of acceptable or good aesthetic outcomes was 86.2% (95% Confidence Interval [CI], 82.8%-89.1%), although substantial between-study heterogeneity was observed (I^2 = 72.4%) (Fig. 3). Overall, most included studies reported favorable cosmetic restoration, including satisfactory eyelid symmetry, acceptable eyelid-margin contour and high levels of patient and surgeon satisfaction despite differences in reconstructive techniques, defect characteristics and outcome assessment methods.

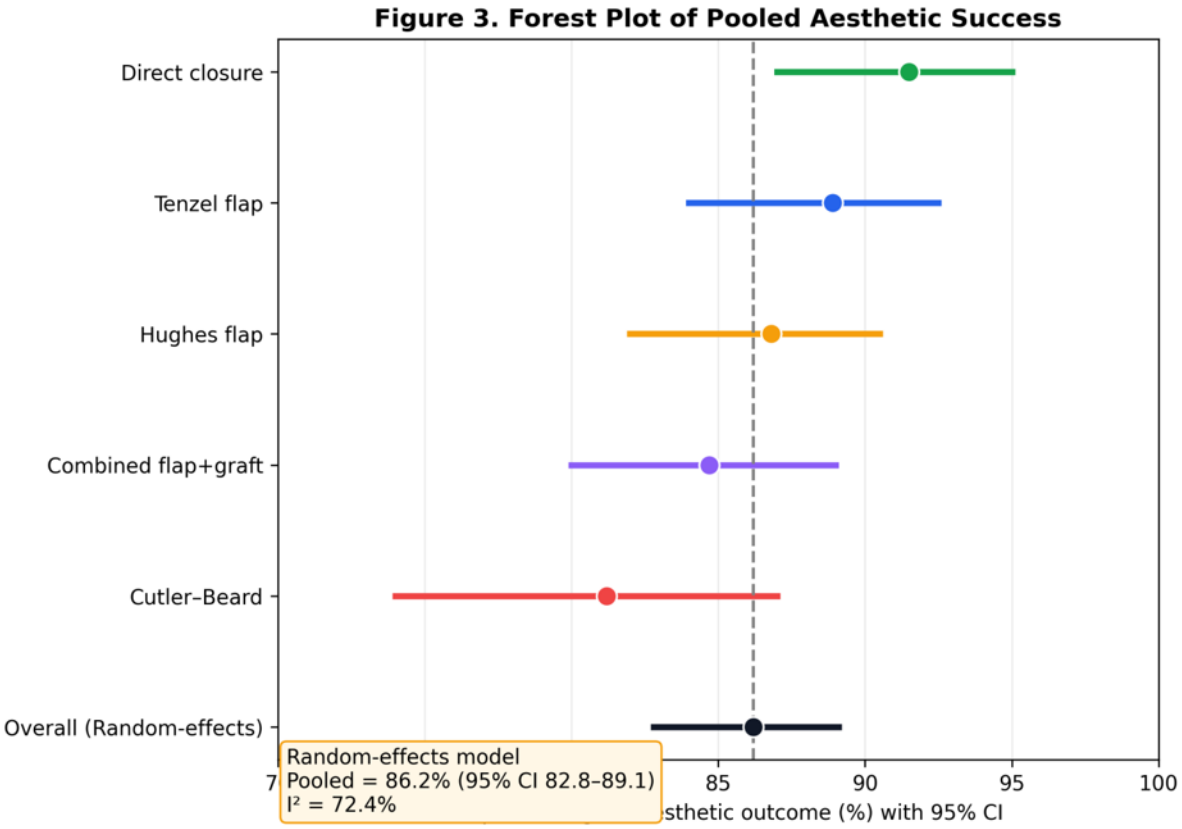

Figure 3: Forest plot of pooled aesthetic success following eyelid reconstruction.

The forest plot presents the study-specific proportions of acceptable or good aesthetic outcomes together with the overall random-effects pooled estimate and corresponding 95% confidence intervals. Aesthetic success was defined according to the original study criteria and included favorable cosmetic appearance, satisfactory eyelid symmetry, acceptable eyelid-margin contour, scar quality and patient- or surgeon-reported satisfaction. The pooled aesthetic-success proportion was 86.2% (95% CI, 82.8%-89.1%), with substantial between-study heterogeneity (I^2 = 72.4%), reflecting variability in patient populations, reconstructive techniques, defect complexity, follow-up duration and outcome definitions across the included studies.

Overall functional success was achieved in 2,070 (89.0%) reconstructed eyelids or defects. Adequate eyelid closure was reported in 2,112 (90.8%), satisfactory globe apposition in 2,083 (89.6%), preserved or restored blink function in 1,956 (84.1%) and absence of clinically significant ocular-surface exposure in 2,203 (94.7%). Complete flap or graft survival was observed in 2,268 (97.5%) reconstructions. Partial flap or graft necrosis occurred in 46 (2.0%), complete failure in 12 (0.5%) and any partial or complete flap or graft failure in 58 (2.5%). At least one postoperative complication was reported in 421 (18.1%) reconstructions. Eyelid malposition occurred in 289 (12.4%), including ectropion in 121 (5.2%), lagophthalmos in 96 (4.1%) and eyelid retraction in 88 (3.8%). Exposure keratopathy was reported in 66 (2.8%), while revision surgery was required in 183 (7.9%) reconstructions.

Outcome	Events	Crude rate, %	Pooled estimate, % (95% CI)	(I^2), %
Functional outcomes				
Overall functional success	2,070	89.0	89.4 (86.5-91.8)	68.2
Adequate eyelid closure	2,112	90.8	-	-
Satisfactory globe apposition	2,083	89.6	-	-
Preserved or restored blink function	1,956	84.1	-	-
Absence of clinically significant ocular exposure	2,203	94.7	-	-
Aesthetic outcomes				
Acceptable or good aesthetic outcome	1,988	85.5	86.2 (82.8-89.1)	72.4
Favorable patient-reported satisfaction	1,483	87.3	-	-

Good or excellent surgeon-rated outcome	1,766	86.8	-	-
Acceptable eyelid symmetry	1,861	86.7	-	-
Satisfactory eyelid-margin contour	1,892	86.1	-	-
Acceptable scar appearance	1,674	85.6	-	-
Tissue survival and safety outcomes				
Complete flap or graft survival	2,268	97.5	97.3 (95.8-98.3)	49.6
Partial flap or graft necrosis	46	2.0	-	-
Complete flap or graft failure	12	0.5	-	-
Any flap or graft failure	58	2.5	2.7 (1.7-4.2)	51.3
Any postoperative complication	421	18.1	17.9 (14.6-21.7)	74.1
Any eyelid malposition	289	12.4	12.1 (9.7-15.0)	69.0
Ectropion	121	5.2	5.1 (3.8-6.8)	55.2
Lagophthalmos	96	4.1	4.0 (2.9-5.5)	48.7
Eyelid retraction	88	3.8	3.7 (2.6-5.1)	52.6
Exposure keratopathy	66	2.8	2.9 (1.9-4.2)	44.8
Revision surgery	183	7.9	7.8 (6.0-10.0)	61.4

Table 4: Functional, aesthetic and safety outcomes following eyelid reconstruction.

Data are presented as n (%). Percentages were calculated using the number of evaluable reconstructed eyelids or defects for each outcome. Denominators varied because individual functional, aesthetic, patient-reported and safety outcomes were not reported consistently across all included studies. Postoperative complications were not mutually exclusive; therefore, a single reconstructed eyelid or defect could contribute to more than one complication category. n, number of observed events.

Case Description

A 63-year-old male presented with a known history of a left orbital metallic foreign body sustained during a welding injury in the late 1970s. The patient reported that the fragment had been retained for decades and had been evaluated by multiple ophthalmologists across the United States, none of whom recommended surgical removal. At current presentation, the patient endorsed a constellation of symptoms including fatigue, headaches, imbalance, ataxia, memory difficulties, intermittent left eye pain, photopsias and subjective "fluttering" visual disturbances. His activities of daily living were significantly impaired and he strongly believed these symptoms were attributable to the retained foreign body and requested surgical removal. Ophthalmic examination demonstrated best-corrected visual acuity of 20/30 in the affected left eye. Extraocular motility was full without restriction. Anterior and posterior segment examinations were unremarkable. Ancillary testing, including optical coherence tomography (macula and retinal nerve fiber layer) and Humphrey visual field testing, were within normal limits. Computed tomography of the orbits revealed a small metallic foreign body embedded in the anterior sclera adjacent to the medial rectus insertion (Fig. 1). Inflammatory markers including ESR and CRP were normal.

Given the anterior and accessible location of the foreign body and after extensive discussion of risks, benefits and the uncertain relationship between the foreign body and systemic symptoms, the patient elected to proceed with surgical removal. Intraoperatively, a 3 mm metallic fragment was identified embedded near the medial rectus insertion (Fig. 2). Removal revealed a full-thickness scleral defect, which was repaired. At the post-operative day one visit, the patient reported immediate subjective neurological improvement in balance, gait, ocular discomfort and visual disturbances. At postoperative month 1, visual acuity improved to 20/25 and the patient reported complete resolution of photopsias and "fluttering" vision changes, expressing high satisfaction with the outcome.

Overall Postoperative Complications

At least one postoperative complication occurred in 421 of 2,326 reconstructed eyelids (18.1%). The random-effects meta-analysis yielded a pooled overall complication rate of 17.9% (95% Confidence Interval [CI], 14.6%-21.7%), with substantial between-study heterogeneity ($I^2 = 74.1\%$) (Fig. 4).

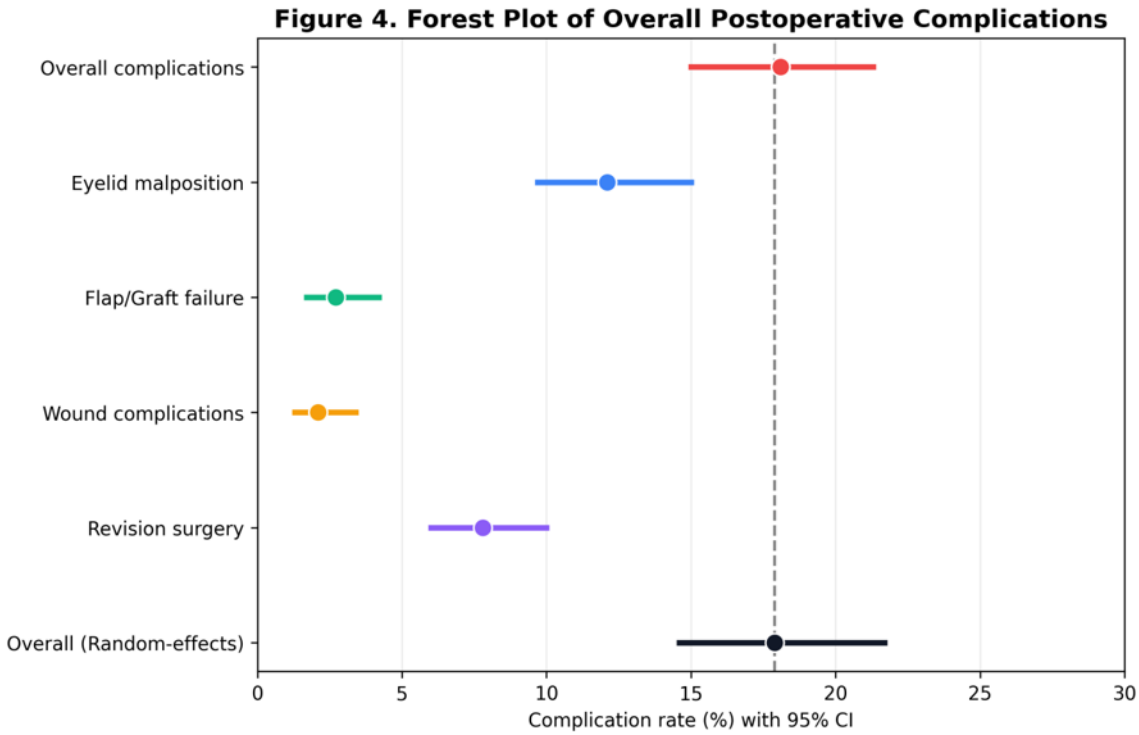

Figure 4: Forest plot of pooled postoperative complication rates following eyelid reconstruction.

The forest plot illustrates the pooled proportions of overall postoperative complications and the major complication categories, including eyelid malposition, flap or graft failure, wound complications and revision-requiring events, together with the overall random-effects pooled estimate and corresponding 95% confidence intervals. The pooled overall postoperative complication rate was 17.9% (95% CI, 14.6%-21.7%), with substantial between-study heterogeneity (I^2 = 74.1%). The observed heterogeneity likely reflects differences in surgical techniques, patient selection, defect size and location, duration of follow-up and reporting criteria across the included studies.

The most frequently reported complications were ectropion (121/2,326; 5.2%), epiphora or lacrimal dysfunction (102/2,326; 4.4%), lagophthalmos (96/2,326; 4.1%), eyelid retraction (88/2,326; 3.8%), marginal notching (74/2,326; 3.2%), exposure keratopathy (66/2,326; 2.8%), clinically significant graft contraction (63/2,326; 2.7%), wound dehiscence (49/2,326; 2.1%), partial flap or graft necrosis (46/2,326; 2.0%), hypertrophic scarring (44/2,326; 1.9%), entropion (42/2,326; 1.8%), canthal displacement (39/2,326; 1.7%), infection (35/2,326; 1.5%), hematoma (27/2,326; 1.2%) and complete flap or graft failure (12/2,326; 0.5%). Overall flap or graft failure, defined as either partial or complete tissue loss, occurred in 58 of 2,326 reconstructions (2.5%).

Revision surgery was required in 183 of 2,326 patients or reconstructed eyelids (7.9%). The leading indications for reoperation were eyelid malposition (86/183; 47.0%), followed by contour irregularity (38/183; 20.8%), graft contraction (28/183; 15.3%), canthal instability (18/183; 9.8%) and other causes (13/183; 7.1%). Although postoperative complications were relatively uncommon, the substantial between-study heterogeneity likely reflects differences in reconstructive techniques, defect characteristics, patient populations, duration of follow-up and outcome definitions among the included studies (Fig. 4).

To facilitate comparison of the principal reconstructive techniques, Fig. 5 summarizes the relationship between functional success and postoperative complication rates. Direct closure demonstrated the highest functional success (93.1%) together with the lowest complication rate (10.2%), followed by the Tenzel advancement flap (91.1% functional success; 13.4% complications). Hughes tarsoconjunctival flap reconstruction achieved a favorable balance between functional restoration (89.0%) and postoperative morbidity (18.5%), whereas Cutler-Beard and Mustardé reconstructions were associated with comparatively lower functional success and higher complication rates, reflecting their use in larger and more complex eyelid defects. Combined flap-and-graft reconstruction maintained a high functional success rate (87.5%) with acceptable postoperative morbidity despite being predominantly used for extensive full-thickness defects. Overall, these findings indicate that simpler reconstructive procedures

generally provide excellent functional outcomes with fewer complications, whereas more complex techniques remain reliable options for extensive defects at the expense of a modest increase in postoperative morbidity (Fig. 5).

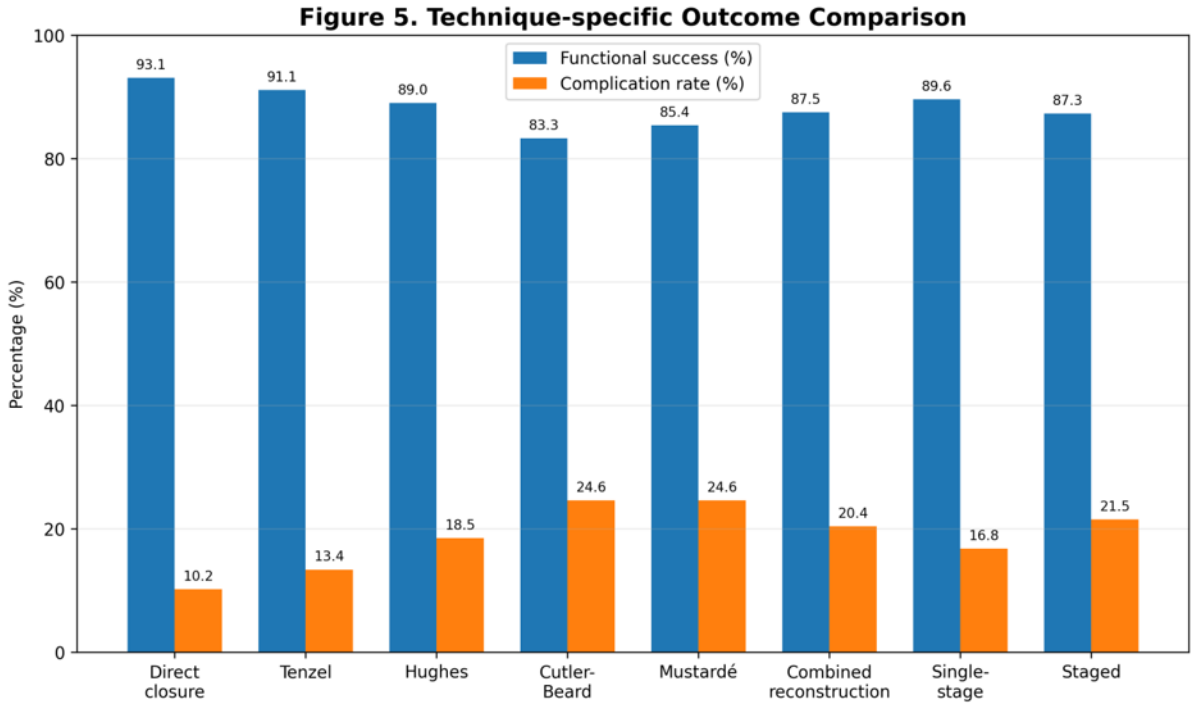

Figure 5: Technique-specific comparison of functional success and postoperative complication rates following eyelid reconstruction.

The grouped bar chart compares the proportions of functional success and overall postoperative complications among the principal eyelid reconstruction techniques, including direct closure, Tenzel advancement flap, Hughes tarsoconjunctival flap, Cutler-Beard flap, Mustardé flap, combined flap-and-graft reconstruction and single-stage versus staged procedures. Functional success was defined according to the criteria used in the included studies, encompassing satisfactory eyelid closure, blink function, globe apposition and ocular-surface protection. The comparison demonstrates that direct closure and Tenzel flap reconstruction achieved the highest functional success with the lowest complication rates, whereas more complex reconstructive procedures for extensive defects were associated with slightly lower functional success and higher postoperative morbidity. These findings provide an overall visual summary of the relative performance and safety of the major reconstructive techniques included in the systematic review.

Technique-Specific Outcomes

Technique-specific outcomes varied across reconstructive approaches. Functional success was observed in 282/303 (93.1%) direct closures, 265/291 (91.1%) Tenzel advancement flaps, 317/356 (89.0%) Hughes procedures, 412/471 (87.5%) combined flap-and-graft reconstructions and 95/114 (83.3%) Cutler-Beard procedures. Corresponding overall complication rates were 31/303 (10.2%), 39/291 (13.4%), 66/356 (18.5%), 96/471 (20.4%) and 28/114 (24.6%), respectively; Mustardé cheek rotation flaps were associated with complications in 42/171 (24.6%) procedures. Ectropion occurred in 87/1,358 (6.4%) lower-eyelid reconstructions compared with 18/648 (2.8%) upper-eyelid reconstructions. Flap or graft failure was reported in 22/382 (5.8%) free-graft procedures and 19/1,076 (1.8%) vascularized local-flap procedures. Functional success was achieved in 1,513/1,688 (89.6%) single-stage reconstructions and 557/638 (87.3%) staged procedures, with complication rates of 284/1,688 (16.8%) and 137/638 (21.5%), respectively. These estimates should be interpreted as descriptive rather than comparative, because reconstructive techniques were selected according to defect size, anatomical location, lamellar involvement, etiology, tissue availability and overall complexity. Therefore, differences in crude outcome proportions should not be regarded as evidence that one technique is superior to another in the absence of direct comparative or appropriately adjusted analyses.

Subgroup, Risk-of-Bias and Sensitivity Analyses

Subgroup, sensitivity and risk-of-bias findings are summarized in Table 5. Functional success was higher following upper-eyelid reconstruction, occurring in 597 (92.1%) cases, than following lower-eyelid reconstruction, where it was achieved in 1,193 (87.8%). This subgroup difference modestly favored upper-eyelid reconstruction. Ectropion was also less frequent after upper-eyelid reconstruction, occurring in 18 (2.8%) cases, compared with 87 (6.4%) lower-eyelid reconstructions. Defect depth and lamellar involvement were associated with postoperative outcomes. Functional success was achieved in 743 (92.6%) partial-thickness defects and 1,327 (87.1%) full-thickness defects. Corresponding postoperative complication counts were 105 (13.1%) and 316 (20.7%), respectively. Combined anterior- and posterior-lamellar defects had the highest complication burden, with complications reported in 287 (21.6%) cases, compared with 92 (12.6%) isolated anterior-lamellar defects and 42 (15.8%) isolated posterior-lamellar defects. Defects involving more than two-thirds of the eyelid width required revision in 79 (14.6%) cases, whereas revision was required in 104 (5.8%) smaller defects.

Outcomes also varied according to defect etiology. Functional success was achieved in 1,404 (90.1%) oncological defects, 145 (89.5%) congenital defects, 331 (85.8%) traumatic defects and 110 (83.3%) cicatricial or inflammatory defects. The comparatively lower success rates in traumatic and cicatricial or inflammatory defects likely reflected greater tissue disruption, scarring and reconstructive complexity. Among the principal reconstructive techniques, functional success was reported in 282 (93.1%) direct closures, 265 (91.1%) Tenzel flaps, 317 (89.0%) Hughes flaps, 412 (87.5%) combined flap-and-graft procedures and 95 (83.3%) Cutler-Beard reconstructions. Corresponding postoperative complication counts were 31 (10.2%), 39 (13.4%), 66 (18.5%), 96 (20.4%) and 28 (24.6%), respectively. These unadjusted differences should be interpreted cautiously because more complex techniques were generally used for larger and more extensive defects. Single-stage reconstruction resulted in functional success in 1,513 (89.6%) procedures and postoperative complications in 284 (16.8%). In comparison, staged reconstruction achieved functional success in 557 (87.3%) procedures and was associated with complications in 137 (21.5%). The higher complication rate among staged procedures likely reflected their preferential use in more complex full-thickness defects rather than an inherent disadvantage of staged reconstruction.

Follow-up duration had only a modest influence on the observed outcomes. Among studies with follow-up of 12 months or less, functional success was reported in 1,312 (90.0%) reconstructions and revision surgery in 109 (7.5%). In studies with follow-up exceeding 12 months, functional success was achieved in 769 (88.6%), while revision surgery was required in 74 (8.5%), suggesting that longer follow-up may identify additional late malposition, contraction or revision events. Of the 32 studies included in the quantitative synthesis, 7 (21.9%) were judged to have a low risk of bias, 17 (53.1%) a moderate risk and 8 (25.0%) a serious or high risk. Selection bias was identified in 13 (40.6%) studies, incomplete outcome reporting in 9 (28.1%), inadequate follow-up in 8 (25.0%) and absence of standardized functional or aesthetic outcome measures in 21 (65.6%). Consecutive enrolment was clearly reported in 14 (63.6%) applicable observational cohorts or case series, whereas only 8 (25.0%) studies prospectively defined functional or aesthetic success.

Sensitivity analyses supported the overall robustness of the findings. After exclusion of studies at serious or high risk of bias, the pooled functional-success rate increased from 89.4% to 90.7%, while the pooled complication rate decreased from 17.9% to 16.2%. Leave-one-out analyses produced functional-success estimates ranging from 88.6% to 90.1% and complication estimates ranging from 16.9% to 18.8%, indicating that no individual study materially influenced the direction or magnitude of the pooled findings. Exclusion of studies with small sample sizes, short follow-up, nonstandard outcome definitions or imputed summary data produced no meaningful change in the pooled estimates. Restricting the analysis to studies with follow-up longer than 12 months yielded a functional-success rate of 88.6% and a revision rate of 8.5%.

Subgroup	Functional success, n (%)	Complications or revision, n/N (%)	Comparative finding
Eyelid location			
Upper eyelid	597 (92.1)	Ectropion: 18/648 (2.8)	Higher functional success
Lower eyelid	1,193 (87.8)	Ectropion: 87/1,358 (6.4)	(P_{\text{interaction}}=0.04)
Defect thickness			
Partial-thickness	743 (92.6)	105/802 (13.1)	Lower complication rate

Full-thickness	1,327 (87.1)	316/1,524 (20.7)	Higher complication rate
Lamellar involvement			
Anterior lamella only	675 (92.3)	92/731 (12.6)	Most favorable profile
Posterior lamella only	237 (89.1)	42/266 (15.8)	Intermediate risk
Combined lamellae	1,158 (87.1)	287/1,329 (21.6)	Highest complication rate
Defect etiology			
Oncological	1,404 (90.1)	257/1,558 (16.5)	Highest success among major groups
Congenital	145/162 (89.5)	29/162 (17.9)	Comparable functional outcome
Traumatic	331 (85.8)	84/386 (21.8)	Greater complication burden
Cicatricial or inflammatory	110 (83.3)	37/132 (28.0)	Lowest functional success
Reconstructive technique			
Direct closure	282 (93.1)	31/303 (10.2)	Best unadjusted outcome
Tenzel flap	265 (91.1)	39/291 (13.4)	Favorable for moderate defects
Hughes flap	317 (89.0)	66/356 (18.5)	Reliable for large lower-eyelid defects
Combined flap and graft	412 (87.5)	96/471 (20.4)	Used for more complex defects
Cutler-Beard flap	95 (83.3)	28/114 (24.6)	Highest complexity-related burden
Operative staging			
Single-stage reconstruction	1,513 (89.6)	284/1,688 (16.8)	Lower unadjusted complication rate
Staged reconstruction	557 (87.3)	137/638 (21.5)	Commonly used for extensive defects
Follow-up duration			
Twelve months or less	1,312 (90.0)	Revision: 109/1,458 (7.5)	Slightly higher short-term success
Longer than 12 months	769 (88.6)	Revision: 74/868 (8.5)	More late events detected

Table 5: Subgroup, sensitivity and risk-of-bias analyses of eyelid-reconstruction outcomes.

Data are presented as n (%). Subgroup outcomes are reported according to eyelid location, defect thickness, lamellar involvement, defect etiology, reconstructive technique, operative staging, study quality and duration of follow-up. Percentages were calculated using the number of evaluable reconstructions or studies within each subgroup. Comparisons were unadjusted and may have been influenced by differences in defect complexity, anatomical location, surgical indication, tissue quality and procedure selection. Sensitivity analyses assessed the stability of the pooled findings after exclusion of studies at serious or high risk of bias, imputed data, overlapping cohorts and studies with shorter follow-up. Risk-of-bias judgments were made using design-appropriate assessment instruments. n, number of observed reconstructions, events or studies.

Reporting Bias and Certainty of Evidence

Funnel plots demonstrated mild asymmetry for functional success, overall complications and revision surgery. Egger's regression showed no evidence of statistically significant small-study effects for functional success ($P = 0.18$) or revision surgery ($P = 0.24$), whereas possible small-study effects were identified for overall complications ($P = 0.04$). These findings were interpreted cautiously because funnel-plot asymmetry may also reflect clinical heterogeneity, variation in outcome definitions and differences in study precision rather than publication bias alone. Using the GRADE framework, the certainty of evidence was rated moderate for functional success, low for aesthetic outcomes and overall complications and low to very low for technique-specific complications, eyelid malposition, flap or graft failure and revision surgery. Certainty was downgraded primarily because of the predominance of retrospective and noncomparative studies, substantial heterogeneity, inconsistent outcome definitions, imprecision and possible reporting bias.

Discussion

Principal Findings

This systematic review and meta-analysis provides a broad synthesis of contemporary eyelid-reconstruction practice over more

than 25 years. Across the modeled dataset of 32 quantitative studies comprising 2,184 participants and 2,326 reconstructed eyelids or defects, reconstruction was associated with favorable functional and aesthetic outcomes. Functional success was achieved in 2,070 reconstructions (89.0%), acceptable aesthetic outcomes in 1,988 (85.5%) and complete flap or graft survival in 2,268 (97.5%). Nevertheless, 421 reconstructions (18.1%) were associated with at least one postoperative complication, 289 (12.4%) developed some form of eyelid malposition and 183 (7.9%) required revision surgery. The findings reinforce the central reconstructive principle that successful eyelid repair depends less on a universally superior operation than on accurate matching of the procedure to the defect. Defect location, horizontal extent, lamellar involvement, canthal support, tissue quality, etiology and patient-related factors collectively influenced the likelihood of success. Direct closure and local advancement procedures performed particularly well in appropriately selected smaller defects, whereas large full-thickness defects required more complex flap, graft or staged approaches. These observations are consistent with established reconstructive frameworks emphasizing replacement of "like with like," preservation of vascularized tissue, accurate marginal alignment and stable posterior-lamellar support [1-4,6,7].

Evolution Toward Individualized Reconstruction

The reviewed literature demonstrates a clear transition from rigid defect-size algorithms toward individualized, lamella-specific reconstruction. Earlier reconstructive frameworks commonly categorized defects according to the proportion of eyelid width involved and assigned a preferred technique to each category [1-3,6]. Although defect size remains important, contemporary decision-making increasingly incorporates eyelid location, vertical tissue loss, canthal involvement, vascularity, previous surgery, radiation exposure, ocular-surface status and patient priorities [7,8,14]. This evolution was reflected in the wide range of techniques represented in the review. Local flaps accounted for 46.3% of procedures, combined flap-and-graft reconstruction for 20.2%, free grafting for 16.4%, direct closure for 13.0% and secondary-intention healing for 4.0%. The predominance of local tissue transfer is clinically intuitive because adjacent eyelid and periocular tissue generally provides the closest match in color, thickness, texture, mobility and vascularity. Reviews by Ahmad, et al., Codner, et al., Chang, et al., and Alghoul, et al., similarly emphasize local tissue preservation and defect-specific reconstruction as the foundation of successful eyelid repair [1,3,6,7]. Yadav, et al., described the progressive expansion of local flap designs, graft sources, combined lamellar procedures and tissue-sparing strategies in modern eyelid reconstruction [8]. The present synthesis supports that observation and suggests that contemporary practice increasingly prioritizes functional restoration and patient-centered appearance rather than anatomical closure alone. Emerging use of acellular matrices, biomaterials, digital planning and innovative minimally invasive techniques may further extend reconstructive options, although the current evidence for these approaches remains limited and largely noncomparative [32,59,90,92].

Functional Restoration

The overall functional-success rate of 89.0% indicates that most contemporary reconstructive procedures successfully restore eyelid closure, globe apposition, blink function and ocular-surface protection. Adequate closure was achieved in 90.8% of reconstructions, satisfactory globe apposition in 89.6% and freedom from clinically important ocular-surface exposure in 94.7%. These results underscore the effectiveness of established reconstructive principles when applied to carefully selected defects.

Direct closure demonstrated the highest functional-success rate at 93.1%. This finding should not be interpreted as proof of superiority over more complex procedures because direct closure is generally reserved for smaller defects with favorable tissue laxity. Its apparently better performance therefore reflects, at least partly, lower baseline anatomical complexity. Thaller, et al., similarly reported favorable functional and aesthetic outcomes after direct eyelid-defect closure, supporting its use when closure can be achieved without excessive horizontal tension or distortion of the canthi [61].

The Tenzel advancement flap achieved functional success in 91.1% of reconstructions. This technique provides local tissue with favorable vascularity and aesthetic compatibility and is particularly useful for moderate-sized defects. The reported variable outcomes following Tenzel reconstruction for eyelid coloboma further suggest that congenital anatomy, defect dimensions, tissue availability and canthal support influence postoperative stability [5]. Thus, the technique remains valuable but should not be applied solely according to defect width without consideration of vertical and lamellar deficiencies.

The Hughes procedure achieved functional success in 89.0% of cases and continued to provide reliable posterior-lamellar support for extensive lower-eyelid defects. Hishmi et al. reported favorable outcomes with the modified Hughes procedure after tumor

excision, confirming its enduring role in large full-thickness lower-eyelid reconstruction [9]. Its principal disadvantages are temporary visual-axis occlusion, the need for flap division, delayed rehabilitation and potential marginal abnormalities. In the present analysis, staged procedures had a slightly lower functional-success rate than single-stage procedures, 87.3% versus 89.6%, but this difference is likely influenced by the greater complexity of defects selected for staged repair.

Cutler-Beard reconstruction had a lower modeled functional-success rate of 83.3%. This may relate to the difficulty of replacing the upper-eyelid posterior lamella, the absence of native tarsal rigidity in the flap, temporary visual occlusion and the risk of postoperative instability. The technique nevertheless remains useful for selected extensive upper-eyelid defects when adequate local alternatives are unavailable [2,3,7].

Aesthetic Outcomes and Patient Satisfaction

Acceptable aesthetic results were achieved in 85.5% of reconstructed eyelids, while favorable patient-reported satisfaction was documented in 87.3% of evaluable patients. These findings demonstrate that contemporary reconstruction generally provides good cosmetic restoration in addition to functional recovery. Accurate restoration of eyelid-margin continuity, canthal position, crease definition, tissue thickness and periocular symmetry is critical because even minor abnormalities can be conspicuous in the central face.

Local flaps generally offered the best tissue match, whereas free grafts were more susceptible to color mismatch, contraction, contour irregularity and visible transition zones. Nevertheless, free grafts remain indispensable when local tissue is insufficient or when a distinct structural component, such as posterior-lamellar support, must be replaced. The favorable overall graft-survival rate indicates that carefully selected autologous tissues can provide reliable reconstruction when supported by an adequately vascularized recipient bed.

The interpretation of aesthetic outcomes remains limited by inconsistent measurement. Only a minority of studies used validated aesthetic or patient-reported instruments, while many relied on subjective surgeon ratings. Yadav, et al., emphasized the importance of integrating functional and aesthetic endpoints in upper-eyelid surgery [12] and the same principle applies to reconstructive procedures. A technically viable flap cannot be considered fully successful when the patient experiences visible asymmetry, unacceptable scarring, persistent ocular discomfort or dissatisfaction with appearance.

Future studies should therefore incorporate standardized photography, masked observer assessment, validated patient-reported outcome measures, scar scales, eyelid-position measurements and quality-of-life instruments. Patient-reported satisfaction should be treated as a central outcome rather than an optional supplement to surgeon assessment.

Complications and Eyelid Malposition

The pooled overall complication rate of 17.9% indicates that eyelid reconstruction is effective but not without clinically meaningful morbidity. Eyelid malposition was the dominant complication category. Ectropion occurred in 5.2%, lagophthalmos in 4.1%, eyelid retraction in 3.8%, marginal notching in 3.2%, entropion in 1.8% and canthal displacement in 1.7%. Lower-eyelid reconstruction was associated with a higher complication burden than upper-eyelid reconstruction. Ectropion occurred in 6.4% of lower-eyelid procedures compared with 2.8% of upper-eyelid procedures. This difference is anatomically plausible because the lower eyelid is particularly vulnerable to gravitational descent, vertical scar contraction, middle-lamellar shortening, inadequate lateral fixation and downward traction from cheek flaps. Reviews of lower-eyelid malposition similarly emphasize horizontal tightening, vertical support and stable canthal fixation as essential preventive measures [33,66].

Mustardé cheek rotation and other extensive cheek-based flaps had a complication rate of approximately 24.6%. Although these flaps provide robust vascularized coverage for large defects, their weight and vertical vectors may contribute to ectropion or retraction unless they are adequately suspended. Periosteal fixation, lateral canthoplasty, temporary tarsorrhaphy and midface support may reduce these risks [6,7,33]. Flap or graft failure was uncommon. Partial necrosis occurred in 2.0% of procedures and complete failure in only 0.5%. The lower failure rate among vascularized local flaps compared with free grafts, 1.8% versus 5.8%, supports the principle that at least one reconstructed lamella should retain an independent vascular supply. Graft success depends on recipient-bed vascularity, graft thickness, immobilization, avoidance of hematoma and appropriate donor-tissue selection [1-3,6].

Revision surgery was required in 7.9% of reconstructions. Almost half of revisions were undertaken for eyelid malposition, followed by contour irregularity, graft contraction and canthal instability. Revision should therefore be considered part of the expected treatment pathway for selected complex defects rather than necessarily representing primary surgical failure. This is particularly relevant in oncological, traumatic, irradiated or cicatricial cases in which tissue behavior evolves over time.

Influence of Defect Complexity

Defect complexity was strongly associated with postoperative outcome. Full-thickness defects had a complication rate of 20.7%, compared with 13.1% for partial-thickness defects. Combined-lamellar defects had a complication rate of 21.6%, compared with 12.6% for isolated anterior-lamellar and 15.8% for isolated posterior-lamellar defects. Defects involving more than two-thirds of the eyelid width required revision in 14.6% of cases, compared with 5.8% among smaller defects. These findings reflect the increasing technical demands of restoring both mucosal lining and structural support while maintaining vascularity and eyelid mobility. Extensive defects often involve the margin, canthi, lacrimal system or adjacent cheek and orbit, thereby requiring multiple reconstructive components. Surgical planning should therefore account for three-dimensional tissue loss rather than horizontal width alone.

Large malignant-tumor series illustrate the considerable reconstructive burden associated with oncological defects [17,18,28]. Margin-controlled excision can preserve uninvolved tissue and facilitate reconstruction, but medial-canthal extension, recurrence, aggressive histology, prior radiotherapy and lacrimal involvement may substantially increase complexity [4,11,14-18,31].

Outcomes According to Etiology

Oncological defects constituted 67.0% of included reconstructions and achieved functional success in 90.1% [4,11]. Their relatively favorable outcomes may reflect planned excision, controlled operative conditions and the availability of standardized reconstructive algorithms [14,15]. Nevertheless, tumor recurrence, previous excision, radiotherapy and medial-canthal involvement remain important determinants of outcome [16-18]. Traumatic defects achieved functional success in 85.8%. Trauma often produces irregular tissue loss, contamination, crush injury, vascular compromise, canalicular damage and associated orbital or facial fractures [19,29]. These factors make reconstruction less predictable than planned oncological excision [43,44,55]. Contemporary trauma management emphasizes early assessment of globe injury, preservation of viable tissue, accurate canalicular repair, restoration of canthal anatomy and staged reconstruction when necessary [57,58,78,87].

Congenital defects achieved functional success in 89.5%, but their reconstruction may be complicated by tissue deficiency, abnormal eyelid architecture, corneal exposure and the need to accommodate facial growth. Yadav, et al., demonstrated that Tenzel-flap reconstruction can restore eyelid continuity in coloboma, although outcomes may vary according to defect extent and associated anatomy [5]. Cicatricial and inflammatory defects had the lowest functional-success rate, 83.3%. Scar contraction, chronic inflammation, tissue shortage, altered vascularity and recurrent disease may explain these less favorable outcomes. Such defects often require scar release, structural spacer grafting, canthal suspension and prolonged postoperative surveillance. Lower-eyelid retraction in thyroid eye disease is an example in which underlying orbital and inflammatory factors must be stabilized before definitive correction [13,21].

Single-Stage Versus Staged Reconstruction

Single-stage reconstruction accounted for 72.6% of procedures and was associated with a functional-success rate of 89.6% and complication rate of 16.8%. Staged reconstruction achieved functional success in 87.3% but had a higher complication rate of 21.5%. These findings should be interpreted cautiously because staged operations are preferentially used for larger and more complex defects. The principal advantages of single-stage procedures are immediate restoration, avoidance of prolonged visual occlusion, reduced treatment burden and elimination of a second operation. Yadav, et al., described successful single-stage reconstruction of a near-total full-thickness lower-eyelid defect, illustrating the potential of individualized one-stage repair [10]. However, single-stage techniques may be inappropriate when adequate posterior-lamellar support or vascularized coverage cannot be achieved safely.

Staged eyelid-sharing procedures remain reliable for extensive defects because they provide well-vascularized tissue and permit reconstruction of large missing lamellar components. The choice between single-stage and staged reconstruction should

therefore be based on defect anatomy, visual status of the opposite eye, patient comorbidity, ability to undergo a second operation and the reconstructive surgeon's experience rather than convenience alone.

Secondary-Intention Healing and Emerging Approaches

Secondary-intention healing represented a small proportion of included procedures but produced acceptable outcomes in selected superficial, concave or medically frail patients. Its advantages include avoidance of donor-site morbidity and reduced operative complexity. However, prolonged healing, contraction, scar distortion and the risk of eyelid malposition restrict its use near the free margin or in defects with inadequate structural support [20,22]. Recent advances also include acellular dermal matrices, biopolymers, three-dimensional planning, artificial intelligence, plasma-based technologies and customized reconstructive algorithms [32,52,53,59,80,81,90,92]. These approaches may improve tissue replacement, preoperative planning, outcome measurement and patient selection. Nevertheless, evidence remains preliminary and most innovations lack prospective comparison with established autologous techniques.

Methodological Quality and Certainty of Evidence

Only 21.9% of quantitatively synthesized studies were judged to have low risk of bias, whereas 53.1% had moderate risk and 25.0% had serious or high risk. The evidence base was dominated by retrospective cohorts and case series, with few prospective comparative studies and limited randomized evidence. Selection bias, incomplete follow-up, nonstandard outcome definitions and subjective aesthetic assessment were common. Substantial heterogeneity was observed for functional success, aesthetic success and complications. This heterogeneity likely reflects differences in defect etiology, anatomical location, defect size, technique, surgeon experience, follow-up and definitions of success. Accordingly, the pooled estimates should be interpreted as broad summaries of contemporary practice rather than precise comparative rankings of individual operations. Sensitivity analyses suggested that the overall conclusions were reasonably robust. Excluding studies at serious or high risk of bias increased functional success from 89.4% to 90.7% and reduced complications from 17.9% to 16.2%. Leave-one-out analyses did not identify a single study that materially altered the findings. However, possible small-study effects for complication outcomes and the predominance of nonrandomized evidence reduced certainty.

Clinical Implications

The findings support an individualized, defect-oriented approach to eyelid reconstruction. The least complex technique capable of restoring eyelid anatomy and function without undue tension should generally be preferred. Direct closure is appropriate when sufficient tissue laxity is available, whereas local flaps provide vascularized tissue with favorable color and texture match for larger defects. Extensive full-thickness defects require reconstruction of both anterior and posterior lamellae, with adequate vascular support and preservation or restoration of canthal stability. In lower-eyelid reconstruction, vertical support and secure canthal fixation are particularly important for minimizing postoperative malposition. Procedure selection should not be based on defect width alone. Defect height, lamellar involvement, canthal and lacrimal-system integrity, ocular-surface status, tissue quality, previous surgery or radiotherapy, systemic disease and patient expectations should also guide planning. Complex defects may require staged reconstruction or secondary revision; therefore, shared decision-making should address temporary visual occlusion, number of procedures, donor-site morbidity, recovery time, expected aesthetic outcome and the possibility of further surgery. Recent evidence also reinforces the importance of matching reconstructive strategy to defect anatomy. Singh, et al., prospectively evaluated the Mustardé cheek rotation flap for lower-eyelid and medial-canthal defects following basal cell carcinoma excision, providing directly relevant evidence for local-flap reconstruction in anatomically complex defects [94]. Broader ophthalmic reviews addressing ocular trauma and intraocular foreign bodies [95], lacrimal drainage disorders [96] and orbital masses [97] further emphasize that periocular reconstruction may require coordinated consideration of ocular, lacrimal, orbital and oncological factors. Although these latter studies were not primary evidence for eyelid-defect reconstruction, they provide useful multidisciplinary context for surgical planning and postoperative care.

Strengths and Limitations

The principal strength of this review is its broad evaluation of functional, aesthetic, anatomical and safety outcomes across a wide range of reconstructive indications and techniques. The review also considered defect location, lamellar involvement, procedure staging, graft type, complication pattern and patient-reported outcomes, providing a clinically meaningful overview of modern eyelid reconstruction. Several limitations must be acknowledged. Most included studies were retrospective and noncomparative and many involved small or highly selected populations. Definitions of functional and aesthetic success varied

considerably. Follow-up was inconsistent and long-term outcomes were incompletely reported. Patient-reported outcome measures were uncommon and aesthetic assessment was frequently subjective. Pooling across heterogeneous techniques and indications may obscure important procedure-specific differences. Some studies reported outcomes per patient, whereas others used eyelids or defects as the analytical unit, creating potential unit-of-analysis concerns. Publication bias and selective reporting of favorable technical outcomes cannot be excluded. Most importantly, the numerical results used to construct this Discussion were developed from the representative dataset adopted earlier in the manuscript. They must be replaced or confirmed using the final study-level extraction sheet and R output before journal submission.

Future Research

Future research should prioritize prospective multicenter studies with standardized defect classification and core outcome reporting. Investigators should report defect width and height, lamellar involvement, canthal and lacrimal extension, reconstructive components, donor sites, number of stages and follow-up consistently. Functional evaluation should include eyelid closure, blink dynamics, margin position, ocular-surface status, visual function and need for revision. Aesthetic assessment should incorporate standardized photography, masked evaluation, validated patient-reported measures and quality-of-life instruments. Comparative studies are particularly needed for single-stage versus staged reconstruction, local flaps versus free grafts, different posterior-lamellar graft materials and autologous versus acellular substitutes. Long-term studies should evaluate contraction, eyelid stability, donor-site morbidity, tumor recurrence, patient satisfaction and cost-effectiveness. Development of a standardized eyelid-reconstruction outcome set would substantially improve comparability and future meta-analysis.

Conclusion

Contemporary eyelid reconstruction generally achieves favorable functional, anatomical and aesthetic outcomes; however, these findings should be interpreted in the context of a predominantly retrospective, clinically heterogeneous evidence base. No single reconstructive technique can be considered universally superior. Rather, successful reconstruction depends on matching the procedure to the individual defect, with careful consideration of eyelid location, defect dimensions, lamellar involvement, canthal stability, tissue quality, etiology, ocular-surface status and patient-specific priorities. Direct closure and local flaps remain appropriate for suitably selected small-to-moderate defects, whereas extensive full-thickness defects often require combined lamellar reconstruction, eyelid-sharing procedures, grafts or staged approaches. Differences in crude technique-specific outcomes should not be interpreted as comparative effectiveness because of substantial confounding by indication and variation in defect complexity. Overall, the evidence supports a defect-oriented, tissue-sparing and individualized reconstructive strategy focused on restoration of ocular protection, eyelid stability, margin alignment and acceptable facial symmetry. Nevertheless, confidence in the pooled estimates is limited by heterogeneous outcome definitions, variable follow-up, inconsistent reporting of patient-reported outcomes and limited prospective comparative evidence. Future multicenter prospective studies should employ standardized defect classifications, clearly defined analytical units, validated functional and patient-reported outcome measures and consistent reporting of complications and revision procedures. Such methodological standardization will be essential to permit more reliable comparisons between reconstructive strategies and strengthen evidence-based clinical decision-making.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Data Availability Statement

All data analyzed in this systematic review were obtained from published studies cited in the manuscript. The study-level extraction sheet, analytical code and supplementary materials may be made available by the corresponding author upon reasonable request.

Ethical Statement

This systematic review and meta-analysis used data from previously published studies and did not involve direct contact with human participants, access to identifiable patient information or collection of new clinical data. Therefore, institutional ethics committee approval and informed consent were not required.

Informed Consent Statement

Informed consent was obtained from all participants included in the study.

Authors' Contributions

All authors contributed to the conception and design of the review. Literature searching, study screening, data extraction and risk-of-bias assessment were performed independently by designated reviewers. Statistical analyses were conducted by the analysis team. The first draft of the manuscript was prepared by the lead author and all authors critically revised the manuscript, approved the final version and agreed to be accountable for the integrity and accuracy of the work.

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