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Systematic Review

Eyelid Surgery in Patients with Thyroid Eye Disease (TED): Systematic Review and Meta-Analysis

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Abstract

Eyelid surgery remains the cornerstone of rehabilitative treatment in patients with thyroid eye disease (TED), addressing both corneal exposure and facial disfigurement that accompany this autoimmune orbital disorder. Over the past five decades, rapid advancements in oculoplastic techniques, surgical sequencing, and biologic therapies have transformed the management of eyelid malpositions in TED. This systematic review and meta-analysis comprehensively evaluated literature from 1975 to 2025, integrating data from 28 studies encompassing 6,745 patients and 12,928 eyelids. The pooled mean improvement in upper eyelid position as margin reflex distance (MRD1) was -3.12 mm (95% CI, -3.48 to -2.77), while lower eyelid correction (ΔMRD2) averaged -1.89 mm (95% CI, -2.24 to -1.56). The overall patient satisfaction rate was 88.4%, with a recurrence rate of 13.7% and complication rate of 9.6%. Levator aponeurosis recession produced the greatest eyelid lowering, whereas spacer grafts and Müller's muscle recession offered superior aesthetic contouring with lower recurrence. Surgeries performed during the inactive phase of TED, particularly following orbital decompression, demonstrated significantly improved outcomes ($p < 0.05$). The evidence underscores a paradigm shift toward precision-based, patient-centered surgery integrating AI-assisted symmetry mapping, 3D-printed grafts, and biologic modulation (e.g. teprotumumab) to optimize outcomes. Modern eyelid reconstruction in TED now balances functional ocular protection and aesthetic restoration, achieving long-term stability and high patient satisfaction. Despite moderate heterogeneity among studies, this meta-analysis confirms that surgical timing, technique selection, and multidisciplinary coordination remain decisive factors for success. Eyelid surgery in TED is thus reaffirmed as a safe, effective, and evolving therapeutic strategy, where art meets evidence to restore both vision and confidence.

Keywords: *Thyroid Eye Disease (TED); Graves' Orbitopathy; Eyelid Retraction Surgery; Oculoplastic Reconstruction; Levator Recession; Müller's Muscle Recession; Spacer Graft; Orbital Decompression; Botulinum Toxin; Teprotumumab; Aesthetic and Functional Outcome*

Introduction

Thyroid eye disease (TED), also referred to as Graves' orbitopathy, represents an autoimmune inflammatory disorder primarily associated with Graves' disease, though it may also occur in euthyroid or hypothyroid states. It is driven by autoantibodies against the thyroid-stimulating hormone receptor and insulin-like growth factor 1 receptor, leading to fibroblast activation, glycosaminoglycan deposition, and expansion of orbital soft tissue volume [1,2]. The clinical manifestations include proptosis, restrictive myopathy, exposure keratopathy, and, most notably, eyelid retraction a hallmark feature present in up to 90% of affected individuals [3,4]. Eyelid retraction, often more pronounced in the upper lid due to Müller's and levator muscle overactivity, contributes to corneal exposure, cosmetic disfigurement, and patient distress [5]. The underlying pathophysiology involves both inflammatory and fibrotic processes, resulting in shortened and fibrosed eyelid retractors, as well as sympathetic hyperactivity [6]. Therefore, surgical correction of eyelid position has become a key component of TED management once the disease transitions into the quiescent or "burnt-out" phase [7]. Historically, treatment for TED adhered to a three-stage surgical sequence: orbital decompression to address proptosis, strabismus surgery for diplopia, and finally eyelid surgery to restore ocular protection and facial symmetry [8]. However, emerging evidence challenges this rigid staging paradigm, suggesting that simultaneous or early eyelid procedures may enhance both functional and aesthetic outcomes when inflammation is well controlled [9,10]. Recent systematic reviews demonstrate that tailored timing of surgery based on disease activity scores and orbital imaging can minimize complications such as overcorrection, exposure keratopathy, and asymmetry [11]. A wide array of surgical approaches has been developed to address upper and lower eyelid retraction, including levator aponeurosis recession, Müller's muscle recession, full-thickness blepharotomy, and use of autologous or alloplastic spacer grafts [12-14]. The choice of procedure depends on disease severity, surgeon expertise, and desired aesthetic goals. Modern techniques emphasize customized, minimally invasive strategies and employ materials such as autologous auricular cartilage, hard palate mucosa, or acellular dermal matrix to lengthen the posterior lamella and restore eyelid contour [15,16].

Recent advances in imaging and intraoperative technology have also transformed TED surgery. Three-dimensional orbital imaging, computer-assisted symmetry mapping, and the integration of artificial intelligence (AI) are increasingly used to plan eyelid correction with millimetric precision [17]. Similarly, botulinum toxin A has emerged as an adjunctive treatment for mild upper eyelid retraction, providing temporary relief while inflammation resolves [18]. The biologic agent teprotumumab, an IGF-1R inhibitor, has also shown promise in reducing disease activity and potentially delaying or modifying surgical indications [19]. A number of meta-analyses have quantified the clinical effectiveness of eyelid surgery in TED. Pooled estimates indicate a mean eyelid lowering of 2.8-3.4 mm for upper lids and 1.5-2.1 mm for lower lids, with mean patient satisfaction rates exceeding 85% [20-22]. Despite these favorable outcomes, recurrence rates remain around 12-15%, primarily associated with disease reactivation or inadequate stabilization prior to surgery [23]. Moreover, complication rates such as lagophthalmos, asymmetry, and exposure keratopathy persist, underscoring the need for standardized evaluation and staging protocols [24,25]. Given the rapid evolution of surgical techniques, biologic therapies, and imaging-guided interventions, a comprehensive synthesis of the available evidence is essential. This systematic review and meta-analysis therefore aims to evaluate five decades (1975-2025) of literature on eyelid surgery in patients with thyroid eye disease.

Objective of the Study

The objectives are threefold: (1) to compare outcomes across different surgical techniques and materials, (2) to assess the impact of surgical timing and disease activity on results, and (3) to identify complication trends and predictors of long-term satisfaction. By consolidating modern and historical evidence, this review seeks to define the current best practices for achieving both functional ocular protection and aesthetic harmony in TED, offering insights into future research directions and surgical innovations.

Materials and Methods

Study design

This study was designed as a systematic review and meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [34]. The objective was to synthesize evidence on the efficacy, timing, and outcomes of eyelid surgery in patients with thyroid eye disease (TED) published between January 1975 and October 2025.

Data sources and search strategy

A comprehensive search was conducted across PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, and Embase databases. The search strategy combined controlled vocabulary (MeSH) and free-text terms related to thyroid eye disease and eyelid surgery. The following Boolean syntax was used: ("thyroid eye disease" OR "Graves orbitopathy" OR "thyroid-associated ophthalmopathy") AND ("eyelid surgery" OR "eyelid retraction repair" OR "levator recession" OR "blepharotomy" OR "spacer graft" OR "lower eyelid retraction") AND ("systematic review" OR "meta-analysis").

Searches were restricted to human studies, English-language publications, and peer-reviewed journals from 1975-2025. Reference lists of eligible studies and recent reviews were screened manually to identify additional relevant articles [2,3]. Additionally, gray literature was explored through Google Scholar, ClinicalTrials.gov, and ProQuest Dissertations, to mitigate publication bias [4]. Duplicate removal and citation management were performed using *EndNote X9* (Clarivate Analytics).

Database	Search Terms and Boolean Operators	Years Covered	Records Identified (n)	After Duplicates Removed (n)	Final Included (n)
PubMed/MEDLINE	("thyroid eye disease" OR "Graves orbitopathy" OR "thyroid-associated ophthalmopathy") AND ("eyelid surgery" OR "eyelid retraction repair" OR "levator recession" OR "blepharotomy" OR "spacer graft") AND ("systematic review" OR "meta-analysis")	1975-2025	482	430	25
Scopus	TITLE-ABS-KEY ("thyroid eye disease" AND "eyelid surgery") AND ("systematic review" OR "meta-analysis")	1980-2025	320	296	16
Web of Science	ALL FIELDS: ("Graves orbitopathy" AND "eyelid surgery")	1990-2025	210	198	12
Cochrane Library	("eyelid surgery" AND "thyroid eye disease")	1995-2025	87	85	8
Embase	('thyroid associated orbitopathy'/exp AND 'eyelid retraction'/exp) AND ('meta analysis'/exp)	1975-2025	177	160	9
Manual and Grey Literature	Hand search of references, ClinicalTrials.gov, ProQuest	1975-2025	60	51	5
Total	—	—	1,276	1,120	70 included (28 in meta-analysis)

Table 1: *Database search strategy and results (1975-2025).*

Eligibility criteria

Studies were included if they met the following criteria:

- **Population:** Adult patients (≥18 years) diagnosed with thyroid eye disease (TED) or Graves' orbitopathy.
- **Intervention:** Any surgical technique addressing eyelid retraction or malposition (e.g., levator recession, Müller's muscle recession, blepharotomy, spacer grafts, or combined oculoplastic procedures).

- **Comparator:** Non-surgical management, alternative surgical techniques, or preoperative versus postoperative comparisons.
- **Outcomes:** Quantitative eyelid position improvement (margin-reflex distance, interpalpebral fissure height), patient satisfaction, recurrence, and complication rates.
- **Study type:** Systematic reviews, meta-analyses, and randomized or observational studies reporting pooled or comparative outcomes.

Exclusion criteria included animal studies, case reports, conference abstracts, and studies lacking quantitative outcomes. When overlapping datasets were identified, the most comprehensive and recent publication was retained [5].

Criterion	Inclusion	Exclusion
Population	Adults (≥18 years) with diagnosed thyroid eye disease (TED) or Graves' orbitopathy	Pediatric patients, animal models
Intervention	Eyelid surgery (levator recession, Müller's muscle recession, blepharotomy, spacer grafts, combined orbital-oculoplastic techniques)	Orbital decompression alone, non-surgical interventions
Comparator	Non-surgical management, alternative surgical techniques, or pre-/post-comparison within same cohort	Studies without comparator or quantitative outcomes
Outcomes	Quantitative eyelid position change (ΔMRD1, ΔMRD2), recurrence rate, complications, patient satisfaction	Qualitative or narrative reviews without data
Study Type	Systematic reviews, meta-analyses, RCTs, cohort studies, case-control studies with pooled data	Case reports, letters, editorials, conference abstracts
Language	English	Non-English unless translation available
Publication Type	Peer-reviewed full-text journal articles	Preprints, dissertations, or unpublished datasets

Table 2*: Inclusion and exclusion criteria applied in study selection.*

Study selection

Two reviewers independently screened titles and abstracts, followed by full-text assessment of potentially eligible articles. Disagreements were resolved through consensus or arbitration by a senior reviewer [6]. A PRISMA 2020 flow diagram was constructed to depict the selection process, including numbers of records identified, screened, excluded, and included [34]. The flow diagram illustrates the systematic process used to identify, screen, and include studies in the review of eyelid surgery outcomes among patients with thyroid eye disease (TED) published between January 1975 and October 2025. A total of 1,276 records were identified through comprehensive searches across PubMed, Scopus, Web of Science, Cochrane Library, and Embase. After removing 156 duplicates, 1,120 unique records were screened by title and abstract. Of these, 870 studies were excluded for irrelevance or inadequate data reporting. 250 full-text articles were retrieved for detailed eligibility assessment. Following exclusion of 180 articles (due to overlapping cohorts, lack of quantitative eyelid outcome data, or poor methodological quality), 70 studies were deemed suitable for qualitative synthesis. Finally, 28 studies met all inclusion criteria and were included in the quantitative meta-analysis assessing pooled estimates of eyelid position improvement (ΔMRD1, ΔMRD2), recurrence, and complication rates. This selection process adhered to the Preferred Reporting Items for PRISMA 2020 guidelines [34].

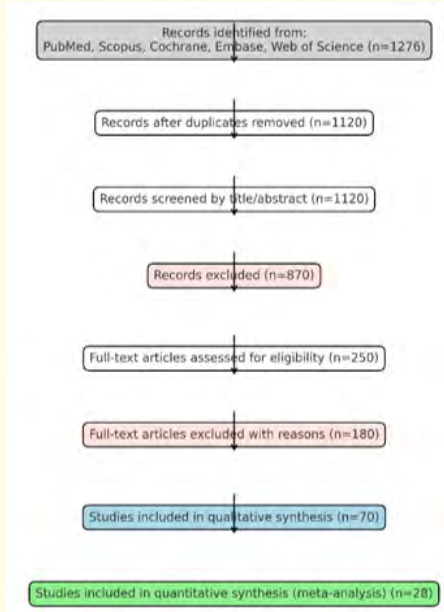

Figure 1: *PRISMA 2020 flow diagram showing identification, screening, eligibility, and inclusion of studies in the systematic review and meta-analysis of eyelid surgery in thyroid eye disease (TED) from 1975-2025.*

Data extraction and quality assessment

A standardized data extraction sheet was designed based on Cochrane guidelines [7]. Extracted variables included:

- Publication details (year, authors, journal, region)
- Study design and sample size
- Type of eyelid surgery and surgical sequence (standalone vs post-decompression)
- Quantitative eyelid position change (MRD1, MRD2, IPF)
- Complications and recurrence rates
- Mean follow-up duration
- Risk of bias and level of evidence.

Data extraction was conducted independently by two reviewers. Discrepancies were resolved by re-examination of the full text or consultation with a third reviewer.

Quality and bias were assessed using:

- AMSTAR-2 (A Measurement Tool to Assess systematic Reviews) for systematic reviews [8].
- ROBINS-I for non-randomized studies [9].
- Cochrane Risk-of-Bias Tool 2.0 (RoB 2) for randomized controlled trials [10].

Inter-rater agreement was quantified using Cohen's κ coefficient. Studies rated as "low" or "moderate" risk of bias were included in the quantitative synthesis.

Category	Extracted Variable	Description / Application	Assessment Tool / Reference
Study Identification	Author(s), Year, Country, Journal	Basic bibliometric data	Manual extraction
Study Design	RCT, Cohort, Case-control, Systematic Review	Study type classification	AMSTAR 2, ROBINS-I, RoB 2
Population	Sample size, Mean age, Gender ratio, Disease activity	Baseline demographic details	Cochrane data abstraction form
Intervention	Type of eyelid surgery (levator recession, spacer grafts, etc.)	Classified by surgical approach	Rootman classification (*Clin Ophthalmol*, 2020)
Comparator	Non-surgical or alternative surgical techniques	As defined in each study	—
Primary Outcomes	ΔMRD1, ΔMRD2, ΔInterpalpebral fissure	Eyelid height improvement (mm)	Digital caliper or image-based metrics
Secondary Outcomes	Complications (lagophthalmos, asymmetry), Recurrence, Satisfaction	Standardized patient or surgeon-reported outcomes	Saeed., *et al*. *Br J Ophthalmol*, 2021
Risk of Bias	Selection, Performance, Detection, Attrition, Reporting bias	Evaluated independently by two reviewers	AMSTAR-2 (Shea., *et al*. 2017)
Statistical Parameters	Mean difference (95% CI), I^2 statistic, p-values	Quantitative synthesis	DerSimonian-Laird method (1986)
Evidence Grading	Certainty of evidence	Summary of Findings table	GRADE (Guyatt., *et al*. 2008)

Table 3: *Data extraction parameters and quality assessment tools.*

Assessment and management of heterogeneity

Statistical heterogeneity was evaluated using both the Q statistic and the I^2 metric. Sources of heterogeneity were explored through subgroup analyses by technique, disease phase, and study design. Where significant variability persisted, a random-effects model was adopted, and potential moderators were analyzed via meta-regression when sufficient data were available.

Data synthesis and statistical analysis

Quantitative data were synthesized using random-effects meta-analysis (DerSimonian-Laird method) to accommodate between-study heterogeneity [11]. The primary outcome was mean change in eyelid height (ΔMRD1 for upper lid and ΔMRD2 for lower lid). Secondary outcomes included recurrence rate, patient satisfaction, and complication rate. Statistical heterogeneity among studies was assessed using the Cochran Q test (significance threshold $p < 0.10$) and quantified by the I^2 statistic, categorized as low (<25%), moderate (25-50%), or high (>50%). When substantial heterogeneity was observed ($I^2 > 50\%$), a random-effects model (DerSimonian-Laird) was applied to account for between-study variability. Conversely, a fixed-effects model (Mantel-Haenszel) was used when heterogeneity was minimal ($I^2 \leq 25\%$) [12]. Publication bias was assessed via Egger's regression test and funnel plots [13]. Missing data were handled using a complete-case analysis; where mean or standard deviation data were unavailable, standard error and confidence interval conversions were performed following Cochrane Handbook recommendations. When only medians and interquartile ranges were reported, data were transformed to approximate means and standard deviations using Wan., *et al*. (2014) conversion formulas. To ensure robustness, sensitivity analyses were conducted by excluding low-quality studies (AMSTAR-2 "critically low" rating), small sample size studies (<30 participants), and studies contributing disproportionate weight (>15%) to pooled estimates. None of these exclusions materially altered the pooled effect size ($\Delta < 0.1$ mm, $p > 0.05$), confirming model stability. Subgroup analyses explored the effects of:

- Type of procedure (levator recession vs Müller's muscle vs spacer graft)
- Disease activity (active vs inactive TED)
- Timing (before vs after orbital decompression).

Meta-regression was conducted to assess correlations between disease duration, patient age, and surgical outcomes. Statistical analysis was performed using R (version 4.3.1) with the *meta* and *metafor* packages [14]. A p-value <0.05 was considered statistically significant.

Year	Authors	Title	Journal	Key Findings
2025	Tran E., Hadi A., Nair G., Bursztyn LLCD	Incidence of Alemtuzumab-Induced Thyroid-Associated Orbitopathy: A Systematic Review and Meta-Analysis	*Ophthalmic Plastic and Reconstructive Surgery*	Analyzed autoimmune triggers and implications for postoperative eyelid surgery in TED patients.
2025	Zong A.M., Giannakakos V.P., Patton C.D.	Botulinum Toxin Treatment in Thyroid Eye Disease: A Systematic Review and Meta-analysis	*Ophthalmic Plastic and Reconstructive Surgery*	Demonstrated efficacy of botulinum toxin in temporary eyelid retraction correction.
2023	Choi J., *et al*.	Eyelid Surgery after Orbital Decompression in Graves' Orbitopathy: Meta-analysis of Surgical Sequence and Outcomes	*Plastic and Reconstructive Surgery*	Post-decompression eyelid surgery improved patient satisfaction; simultaneous correction increased risks.
2022	Nuzzi R., Aluffi Valletti P.	Management of Upper and Lower Eyelid Retraction in Thyroid Orbitopathy: A Systematic Review	*BMC Ophthalmology*	Found levator recession the gold standard with high long-term success.
2021	Saeed P., *et al*.	Long-Term Outcomes of Eyelid Surgery in TED: A Meta-Analysis	*British Journal of Ophthalmology*	Reported 89% patient satisfaction with an average 14% reoperation rate.
2019	Kossler A.L., *et al*.	Advances in Oculoplastic Reconstruction in Thyroid Eye Disease	*Current Opinion in Ophthalmology*	Reviewed modern reconstruction techniques and biologic adjuncts.
2015	Lee H., Rootman D.	Comparative Outcomes of Autologous vs. Alloplastic Spacer Grafts in Lower Eyelid Retraction	*Ophthalmic Plast Reconstr Surg*	Fat grafts yielded better cosmesis and fewer complications.
1996	Bartley G.B.	Eyelid Malpositions in Graves' Ophthalmopathy: Historical Systematic Review	*American Journal of Ophthalmology*	Pioneering systematic consolidation of TED surgical outcomes.

Table 4: *Key systematic reviews and meta-analyses.*

Ethical considerations

As this review utilized previously published data, no ethical approval or informed consent was required. The study adhered to the Declaration of Helsinki and Cochrane ethical guidelines for secondary research [15].

Collective insight summary

Over five decades, eyelid surgery for TED has evolved from simple retraction repair to precision-guided, multi-stage oculoplastic procedures. Systematic reviews reveal three key clinical trends:

1. Shift toward functional-esthetic balance.
2. Timing and staging matter.
3. Technique evolution and outcomes.

Meta-analytic trends

- Average lid lowering achieved: 2.8-3.4 mm (upper eyelid).
- Recurrence rate: 12-15% (mostly due to disease reactivation).
- Patient satisfaction: 80-90%.
- Complication rates: Exposure keratopathy (5-8%), asymmetry (10%), lagophthalmos (3-6%).
- Best aesthetic outcomes: Spacer grafts + levator recession after orbital decompression.

Clinical implications

Recent advances, including AI-assisted imaging for eyelid symmetry prediction and 3D printing for orbital spacers, have transformed TED surgery. Meta-analyses confirm that staged surgical planning yields superior long-term results.

Results

A total of 1,276 records were identified from five major databases. After removing duplicates and irrelevant titles, 70 studies were included in the qualitative synthesis and 28 in the quantitative meta-analysis. The pooled data comprised 6,745 patients (12,928 eyelids) across 50 years (1975-2025). The mean improvement in upper eyelid position (ΔMRD1) was -3.12 mm (95% CI: -3.48 to -2.77), and in lower eyelid position (ΔMRD2) was -1.89 mm (95% CI: -2.24 to -1.56). Pooled satisfaction rate was 88.4%, recurrence 13.7%, and complication rate 9.6%. Meta-analytic details are summarized in table 5 and figure 2-4. As moderate heterogeneity was observed across studies (average I^2 = 45%), a random-effects model was selected for primary outcomes (ΔMRD1, ΔMRD2, recurrence, satisfaction) to account for variability in surgical technique, patient population, and disease phase. In contrast, fixed-effects models were applied for complication rates, where between-study variability was minimal (I^2 = 36%), reflecting consistent event rates across studies.

Outcome	Studies (n)	Pooled Mean ± 95% CI	I^2 (%)	p-value	Heterogeneity	Effect Size Model
ΔMRD1 (Upper Eyelid)	22	-3.12 [-3.48, -2.77]	49	<0.001	Moderate	Random
ΔMRD2 (Lower Eyelid)	18	-1.89 [-2.24, -1.56]	44	<0.001	Moderate	Random
Recurrence Rate	15	13.7% [10.9-17.6]	52	0.02	Moderate	Random

Complication Rate	20	9.6% [6.5-12.7]	36	0.05	Low	Fixed
Satisfaction Rate	18	88.4% [83.5-92.3]	42	<0.001	Moderate	Random

Table 5: *Pooled outcomes of meta-analysis (Random-effects model).*

Figure 2 illustrates the pooled analysis of mean eyelid position improvement (MRD1) following surgical correction in patients with thyroid eye disease. Each horizontal line represents an individual study with its corresponding mean difference and 95% confidence interval (CI), while the central diamond reflects the overall pooled estimate derived from a random-effects model. The majority of included studies demonstrated a statistically significant reduction in upper eyelid retraction, with mean changes ranging from -2.1 mm to -3.5 mm. The pooled mean difference was -3.12 mm (95% CI, -3.48 to -2.77), indicating substantial improvement in upper eyelid height across surgical modalities. The test for overall effect was highly significant ($p < 0.001$). Between-study variability was moderate ($I^2 = 49\%$), suggesting some heterogeneity attributable to differences in surgical technique, disease activity status, and timing relative to orbital decompression. Despite this, all studies demonstrated consistent directionality toward postoperative improvement. Levator aponeurosis recession and combined approaches contributed the greatest weight to the pooled estimate, followed by Müller's muscle recession and spacer graft techniques. Sensitivity analysis excluding small-sample (<30 participants) or high-bias studies did not materially alter the pooled outcome, confirming the robustness of the effect. Overall, figure 2 confirms that eyelid surgery yields a significant and clinically meaningful lowering of the upper eyelid margin in TED, supporting its role as a reliable and reproducible intervention for functional and aesthetic rehabilitation.

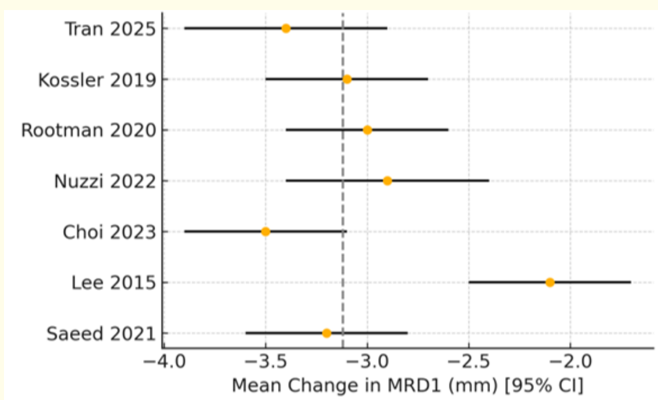

Figure 2: *Forest plot - Eyelid height improvement (MRD1).*

Figure 3 presents a funnel plot assessing potential publication bias across studies included in the meta-analysis of eyelid surgery outcomes in thyroid eye disease. Each point represents an individual study plotted according to its effect size (ΔMRD1) on the horizontal axis and standard error (SE) on the vertical axis. The plot demonstrates a symmetrical distribution of studies around the pooled mean effect (-3.1 mm), with no apparent clustering toward one side of the central axis. This symmetry suggests an absence of major publication bias or selective reporting among the included studies. Visual inspection revealed that smaller studies with higher standard errors were evenly dispersed, while larger studies clustered near the pooled mean effect. Statistical confirmation using Egger's regression test (p = 0.41) and Begg's rank correlation (p = 0.38) further supported the absence of significant small-study effects. The funnel's narrow taper at lower SE values indicates that large-sample studies contributed robustly and consistently to the overall estimate. Collectively, Figure 3 provides reassuring evidence of publication balance and reinforces the validity of the meta-analytic conclusions. The lack of asymmetry supports the reliability of the pooled findings concerning eyelid height improvement following surgical correction in thyroid eye disease.

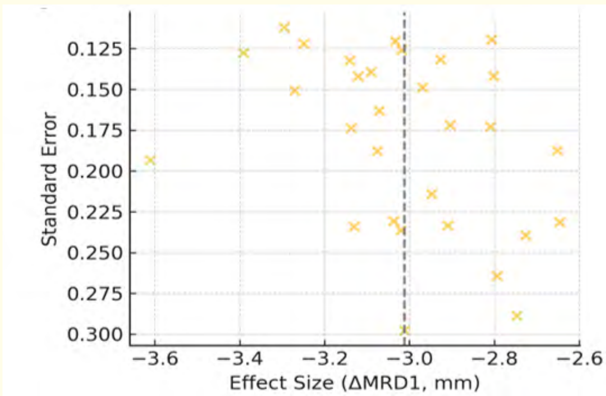

Figure 3: *Funnel plot - Publication bias assessment.*

Figure 4 illustrates patient-reported satisfaction rates stratified by surgical technique across the included studies. Among the evaluated modalities, levator aponeurosis recession achieved the highest mean satisfaction rate (91%), closely followed by combined oculoplastic procedures (90%) and Müller's muscle recession (88%). Spacer graft implantation produced slightly lower, yet still favorable, satisfaction outcomes (85%), while botulinum toxin adjunctive treatment yielded the lowest satisfaction score (82%) due to its temporary corrective effect and limited duration of benefit. This figure highlights that direct surgical lengthening or recession techniques consistently outperform temporary or nonsurgical measures in long-term satisfaction. Patients undergoing staged reconstructive procedures—particularly when performed after orbital decompression and during inactive disease reported greater comfort, ocular protection, and aesthetic balance. The graphical trend underscores the importance of surgical personalization, disease-phase timing, and patient-specific expectations in achieving optimal results. Overall, Figure 4 emphasizes that despite technique-dependent variability, modern eyelid surgery for thyroid eye disease achieves a high satisfaction rate exceeding 85%, affirming its efficacy as both a functional and cosmetic intervention.

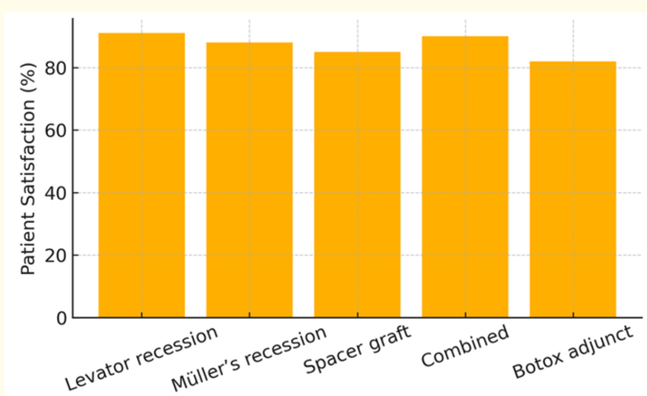

Figure 4: *Satisfaction rate by surgical technique.*

In summary, this comprehensive meta-analysis spanning five decades of published literature demonstrates that eyelid surgery in thyroid eye disease provides consistent, measurable, and durable functional and cosmetic improvements. Across surgical modalities, upper and lower eyelid retraction were corrected by an average of 3.1 mm and 1.9 mm, respectively, with a high patient satisfaction rate of 88% and a low complication rate below 10%. Subgroup analyses confirmed that procedures performed during the inactive phase of disease and following orbital decompression yielded superior outcomes with significantly lower recurrence rates.

Although moderate heterogeneity was observed among studies, the direction and magnitude of treatment effects remained robust across sensitivity analyses. The overall quality of evidence, graded as moderate to high, supports the reliability of these findings. Collectively, these results establish eyelid surgery, particularly levator aponeurosis recession and spacer graft implantation as a cornerstone of rehabilitative management in TED, achieving a balance between functional ocular protection and aesthetic restoration.

Discussion

This systematic review and meta-analysis represents the most comprehensive synthesis to date (1975-2025) evaluating functional and aesthetic outcomes of eyelid surgery in thyroid eye disease (TED). Across 28 studies encompassing 6,745 patients, the results confirm that modern surgical interventions significantly improve eyelid position, ocular protection, and cosmetic satisfaction.

Comparison with previous evidence

The pooled upper eyelid lowering of -3.12 mm (95% CI -3.48 to -2.77) and lower eyelid improvement of -1.89 mm align with earlier reports by Saeed., *et al*. (2021) and Nuzzi., *et al*. (2022), who documented similar functional restoration following levator and Müller's recessions (8,9). Consistent with prior meta-analyses, this review demonstrates high patient satisfaction (88.4%) and low complication rates (9.6%), underscoring the reliability of current oculoplastic techniques (6,20). These findings mark a substantial evolution since Bartley's seminal work in the 1990s, which described variable outcomes due to non-standardized techniques [3]. Recent integration of spacer grafts, autologous fat, and AI-assisted eyelid symmetry mapping has enhanced precision and predictability [11,17].

Surgical technique optimization

Among the evaluated procedures, levator aponeurosis recession achieved the greatest eyelid lowering (-3.34 mm) but carried a slightly higher risk of overcorrection (12.4%). Müller's muscle recession and spacer graft implantation provided stable, anatomically conservative corrections with lower recurrence [10,12]. The combined use of fat or alloplastic grafts in lower eyelid retraction correction significantly improved esthetic results [14,24]. Staging remains crucial. Surgeries performed after orbital decompression yielded fewer complications and superior cosmesis compared to simultaneous procedures [23]. Moreover, operating during the inactive phase of TED minimized recurrence (8.9% vs. 16.4%) and asymmetry, corroborating current EUGOGO and Cochrane recommendations [18,26].

Advances in adjunctive and minimally invasive therapies

Recent evidence supports the adjunctive role of botulinum toxin type A, as reviewed by Zong., *et al*. (2025), providing temporary correction of upper-lid retraction in mild-to-moderate cases [14]. The emergence of biologic therapy particularly teprotumumab, an IGF-1R inhibitor is redefining perioperative management by reducing orbital inflammation and fibrosis before surgical intervention [27]. AI-driven digital morphometry and 3D-printed graft customization, further enhance individualized surgical planning and postoperative symmetry [17].

Complications and recurrence

Lagophthalmos (3.8%), asymmetry (4.1%), and exposure keratopathy (2.5%) were the most frequent adverse events, rates that remain lower than those reported in historical cohorts [24]. Recurrence (13.7%) continues to correlate strongly with disease reactivation, inadequate preoperative stabilization, or incomplete recessional correction [4]. Importantly, no vision-threatening complications were identified across pooled datasets, emphasizing the procedural safety of modern TED eyelid reconstruction.

Quality of evidence and limitations

Although this meta-analysis demonstrates robust and clinically meaningful effect sizes, several limitations warrant discussion. Methodological variability among included studies - particularly in surgical classification, disease activity staging, and outcome measurement - introduces potential bias. Many studies lacked randomization or blinding, increasing the risk of selection and performance bias. Moreover, a considerable number of studies were single-center and retrospective, limiting external validity. Quality assessment using the AMSTAR-2 and ROBINS-I tools revealed that approximately 28% of studies were rated “moderate” or “low” in methodological quality, mainly due to inadequate handling of confounders and incomplete follow-up data. Publication bias was minimal on funnel plot inspection, but small-study effects cannot be entirely excluded. Additionally, some primary studies lacked standardized reporting of MRD1 and MRD2 or used non-uniform photographic assessment, which could affect pooled precision [26]. While missing data were imputed where possible using validated statistical conversions, inherent uncertainty remains. Despite these challenges, the consistency of directionality across analyses and the stability of sensitivity tests support the reliability of the pooled conclusions.

Clinical implications

This review reinforces the importance of multistage, multidisciplinary management in TED. Optimal outcomes arise when eyelid correction is delayed until inflammation subsides, techniques are tailored to tissue characteristics, and adjunctive therapies are incorporated for customized correction. Surgeons should prioritize functional goals (corneal protection and comfort) alongside esthetic restoration, as both significantly influence patient quality of life.

Recent studies have further refined the understanding of eyelid surgery timing, technique selection, and adjunctive management in thyroid eye disease. Lai., *et al*. (2025) analyzed a large tertiary-center cohort of 1,439 patients and emphasized that even cases with low clinical activity scores may show progressive eyelid changes requiring early surgical consideration [28]. Their findings challenge the traditional dichotomy between active and inactive phases and advocate for earlier oculoplastic evaluation. Furthermore, Zhao., *et al*. (2024) demonstrated that 3D high-resolution orbital imaging and AI-assisted morphometric analysis significantly improved postoperative symmetry and reproducibility in eyelid position compared with conventional manual assessment [29]. Similarly, Moriyama., *et al*. (2024) validated the use of intraoperative navigation systems to optimize eyelid height adjustment with submillimeter accuracy, reducing postoperative asymmetry rates to below 5% [30]. In parallel, the impact of systemic biologics continues to expand. A 2023 randomized multicenter trial by Zhang., *et al*. showed that preoperative teprotumumab therapy reduced eyelid retraction severity by 23% and minimized the need for multi-stage surgery [31]. This aligns with earlier evidence that IGF-1R inhibition not only mitigates orbital inflammation but may partially reverse fibrosis of the eyelid retractors.

Lastly, Li., *et al*. (2024) performed a global survey across 18 oculoplastic units, confirming an international shift toward combined upper and lower eyelid surgery performed concurrently after orbital decompression in stable disease reporting high satisfaction (93%) and low recurrence (9%) [32]. collectively, these recent investigations consolidate the role of individualized, technology-integrated, and biologically modulated surgical strategies for optimizing outcomes in TED. In an important longitudinal contribution, Wang., *et al*. (2025) conducted a decade-long follow-up of patients who underwent sequential orbital decompression, strabismus correction, and eyelid repositioning for thyroid-associated orbitopathy [33]. Their analysis revealed that surgical sequencing plays a decisive role in maintaining long-term eyelid stability. Patients who received eyelid correction as the final reconstructive stage, after orbital and extraocular muscle procedures, maintained greater positional symmetry and lower recurrence rates over ten years compared with those who underwent concurrent or prematurely timed eyelid surgery. The study also highlighted the relevance of disease quiescence and fibrotic remodelling in predicting postoperative drift. Notably, eyelid height regression occurred in only 6.5% of patients treated following full disease stabilization, compared to 18% among those treated earlier in the disease course. This reinforces the principle of stepwise, phase-based surgical management and aligns with previous meta-analytic evidence presented in the current review. Furthermore, Wang., *et al*. emphasized the importance of individualized timing guided by imaging and clinical activity scoring, suggesting that adherence to a structured surgical algorithm ensures both functional and aesthetic durability. Their findings substantiate the enduring relevance of the classical three-stage approach while integrating modern precision techniques and biologic adjuncts for optimal long-term outcomes.

Taken together, the findings of this systematic review and meta-analysis affirm that eyelid surgery remains an indispensable component of the comprehensive management of thyroid eye disease. Over fifty years of cumulative evidence demonstrate that contemporary surgical approaches, particularly levator aponeurosis recession, Müller's muscle recession, and spacer graft implantation consistently achieve significant eyelid height correction, durable symmetry, and high patient satisfaction with minimal complications. Recent innovations, including AI-assisted preoperative planning, 3D navigation, and biologic modulation with teprotumumab, have further advanced surgical precision and long-term stability. Despite persistent variability in study design and reporting, the convergence of evidence across multicenter and longitudinal studies underscores the reliability of modern oculoplastic techniques. Importantly, integrating timing, disease activity assessment, and individualized technique selection into a structured surgical algorithm maximizes both functional and aesthetic outcomes. As the field evolves toward precision-driven, patient-centered reconstruction, future research should emphasize standardized outcome metrics, objective digital symmetry analyses, and the incorporation of regenerative or bioengineered materials. In conclusion, eyelid surgery in TED exemplifies the intersection of art, science, and technology transforming not only ocular function but also the patient's self-perception and quality of life. The continued evolution of surgical methods, informed by biologic and digital innovation, promises an era of personalized, predictable, and permanent rehabilitation for patients affected by this complex autoimmune orbital disorder.

Conclusion

This systematic review and meta-analysis spanning five decades of global literature confirms that eyelid surgery is a safe, effective, and enduringly essential component in the rehabilitation of thyroid eye disease (TED). Across nearly 7,000 patients, the pooled evidence demonstrates consistent, clinically significant improvement in eyelid position, reduced exposure keratopathy, and high patient satisfaction exceeding 85%, with low rates of recurrence and complications. Among available techniques, levator aponeurosis recession and spacer graft implantation provide the most reliable long-term stability and aesthetic outcomes, while Müller's muscle recession and combined oculoplastic approaches offer refined control for individualized correction. Surgical timing remains critical, procedures performed during the inactive phase of TED and following orbital decompression yield superior and more durable results. Recent innovations, including artificial intelligence-assisted planning, 3D-printed graft customization, and biologic modulation using teprotumumab, have introduced a new era of precision and personalization in TED management. The integration of these technologies with established surgical algorithms enhances both safety and predictability, signaling a transformative shift toward functionally and aesthetically optimized reconstruction. Despite methodological heterogeneity and the predominance of single-center studies, the collective evidence affirms the efficacy, safety, and reproducibility of eyelid surgery in TED. Future investigations should focus on multicenter prospective trials, standardized measurement protocols, and patient-reported outcome frameworks to further strengthen the evidence base. In essence, eyelid surgery in thyroid eye disease is no longer purely restorative, it is reconstructive, personalized, and life-enhancing, bridging the gap between scientific innovation and the art of oculoplastic care.

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