DOI: XXX

REVIEW ARTICLE

Artificial intelligence and machine learning in blepharoplasty procedure: a systematic review and meta-analysis

Abdulrhman Abdulaziz Alnoshan[1*], Yousef Mesaed Al-Shammari[2], Abdulelah Abdullaha A. Alanazi[3], Noura almarri[4], Jaber Ali Alharbi[5], Fay Abdulrahman Hamad Alshalan[6], Walaa Fahad Almutawa[1], Mohammed Ahmed Ali Argabi[7], Lojain Mohammed A Maawadh[8], Abdullah Altamimi[9]

ABSTRACT

Introduction: Artificial intelligence (AI) and machine learning (ML) are revolutionizing surgical fields, including oculoplastic surgery. In blepharoplasty, these technologies offer objective analysis of eyelid morphology, age estimation, and surgical outcomes, potentially enhancing both cosmetic and functional results. This systematic review and meta-analysis aimed to evaluate the diagnostic performance and applications of AI/ML in blepharoplasty procedures.

Methods: Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, four databases (PubMed, Embase, Scopus, and Web of Science) were searched through June 2025. Eligible studies included original research evaluating AI/ML tools for blepharoplasty-related assessments. Data extraction and quality assessment (NIH tool) were independently conducted by two reviewers. A diagnostic test accuracy meta-analysis was performed using MetaDisc 2.0 and RevMan 5.4.1 to pool sensitivity and specificity data, with heterogeneity assessed via I^2.

Results: Of 944 records identified, 12 studies met inclusion criteria. Eight were rated as good quality. Pooled analysis of four studies assessing AI-based blepharoptosis detection showed a sensitivity of 83% [95% confidence interval (CI): 0.67-0.92] and specificity of 84% (95% CI: 0.83-0.86). Two studies demonstrated the ability of AI models to quantify post-operative age reduction, with reductions ranging from 2 to 5 years. Five studies evaluated AI's role in eyelid morphology assessment, with several demonstrating high accuracy and reproducibility comparable to expert clinicians. Ethical concerns, particularly data diversity, were also highlighted.

Conclusion: AI and ML technologies show promising utility in blepharoplasty for diagnosing blepharoptosis, assessing eyelid morphology, and estimating rejuvenation outcomes. Further large-scale, diverse, and prospective studies are needed to support integration into clinical practice.

Keywords: Artificial intelligence, machine learning, blepharoplasty, surgery.

Introduction

Artificial intelligence (AI) and machine learning (ML) have emerged as transformative technologies in modern medicine, particularly in surgical specialties [1]. These computational approaches enable the analysis of complex medical data to improve diagnostic accuracy, enhance surgical planning, and predict patient outcomes [2]. In ophthalmology and oculoplastic surgery, AI applications have demonstrated remarkable potential, ranging from retinal disease detection to periocular surgery

Correspondence to: Abdulrhman Abdulaziz Alnoshan
*College of Medicine, King Saud University, Riyadh, Saudi Arabia.
Email: alnoshan.AA@gmail.com
Full list of author information is available at the end of the article.
Received: 07 July 2026 | **Accepted:** 12 July 2026

optimization [3]. This systematic review focuses on the application of AI and ML in blepharoplasty procedures, a common oculoplastic surgery addressing functional and esthetic eyelid concerns.

The integration of AI in surgery has progressed significantly, with algorithms now capable of assisting in pre-operative assessment, intraoperative guidance, and post-operative evaluation [4]. In cosmetic and reconstructive surgery, AI-powered tools provide objective measurements that complement traditional clinical judgment, reducing subjectivity in decision making [5]. Specifically for blepharoplasty, AI applications have shown promise in quantifying surgical outcomes, with studies demonstrating the ability of deep-learning models to measure post-operative rejuvenation effects by estimating apparent age reduction [6]. ML approaches, particularly convolutional neural networks (CNNs), have revolutionized the assessment of eyelid morphology [7]. Automated image analysis systems can now precisely measure critical parameters such as margin reflex distance (MRD1 and MRD2), palpebral fissure height, and upper eyelid contour with accuracy comparable to expert clinicians [8]. These technological advancements address long-standing challenges in oculoplastic surgery, including the subjectivity of manual measurements and inter-observer variability in clinical assessments [9]. Furthermore, AI algorithms have been developed to diagnose blepharoptosis from standard clinical photographs without requiring specialized equipment or reference markers, demonstrating sensitivities exceeding 90% in some studies [10].

The role of ML in blepharoplasty extends across the surgical continuum [5]. Preoperatively, generative adversarial networks can simulate potential surgical outcomes, enhancing patient counseling and expectation management [11]. Intraoperatively, computer vision systems provide real-time feedback on eyelid symmetry and contour [8]. Postoperatively, deep-learning models objectively quantify results by analyzing changes in eyelid position, exposed corneal area, and overall facial harmony [7]. These applications not only improve surgical precision, but also facilitate standardized outcome assessment in clinical research.

Despite these advancements, several limitations persist in current AI applications for blepharoplasty [10]. Dataset biases, particularly the underrepresentation of diverse ethnic groups and older patients, may limit algorithm generalizability [12]. In addition, many studies have focused on static image analysis rather than dynamic eyelid function assessment [9]. The clinical integration of these technologies also faces challenges regarding workflow adaptation and validation in real-world settings [13]. This systematic review and meta-analysis aim to comprehensively evaluate the current evidence regarding AI and ML applications in blepharoplasty procedures.

Methods

This systematic review and meta-analysis were performed following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and the Cochrane Handbook for Systematic Reviews of Interventions.

Data sources and eligibility criteria

Web of Science, PubMed, Embase, and Scopus were searched from inception to June 2025 using a comprehensive search strategy using the MeSH database for medical terms. The full search strategy with the results from each study is available in Table S1. Also, we have screened all the included studies to ensure that we include all the eligible studies.

The inclusion criteria for this systematic review and meta-analysis were as follows: studies had to investigate the use of AI or ML in blepharoplasty procedures, including both functional and cosmetic applications. Eligible studies reported relevant outcomes such as the identification or prediction of blepharoptosis, assessment of perceived age reduction following surgery, or evaluation of eyelid morphology and esthetic outcomes. Only original research articles, such as observational studies, diagnostic accuracy studies, and AI model evaluations, published in English with full-text availability were considered. Studies were excluded if they did not involve AI or ML in the context of blepharoplasty, were not original research (reviews, editorials, and case reports), were published in a language other than English, or focused on AI tools unrelated to clinical or surgical assessment (studies evaluating ChatGPT or question-answering models).

Study selection and data extraction

The study selection process was conducted using Covidence by two independent authors. After removing duplicates, a two-step screening approach was implemented. First, titles and abstracts were screened to exclude irrelevant studies. Next, the remaining articles underwent full-text review to assess eligibility based on the predefined inclusion and exclusion criteria. Any disagreements between authors during the selection process were resolved through discussion and mutual consensus. Following the identification of eligible studies, a pilot data extraction was performed to develop a structured Excel-based extraction form. The finalized form consisted of three main sections: (1) general study information, including the first author's name, country, year of publication, and main findings; (2) baseline characteristics relevant to the scope of this review; and (3) outcomes data focused on diagnostic accuracy metrics. Specifically, for each included study, the authors extracted sensitivity, specificity, and other relevant statistics for conducting a diagnostic test accuracy meta-analysis. All data were extracted independently by two authors, and any discrepancies were resolved through discussion with input from a senior author when necessary.

Risk of bias

The quality of the included cohort studies was assessed using the NIH Quality Assessment Tool. This instrument evaluates 14 key methodological criteria, including the clarity of the research question, the adequacy of participant selection and description, the methods used for exposure and outcome assessment, control for confounding variables, and the appropriateness of the statistical analyses. Each item was rated as "yes" (scored as 1), "no" (0), or "other" (e.g., not applicable or cannot determine). The overall quality score for each study was calculated by summing the number of "yes" responses, with a maximum possible score of 14. Based on these scores, studies were classified as good quality (10-14), fair quality (5-9), or poor quality (0-4). Any discrepancies in the quality ratings were resolved through discussion among the authors in consultation with the senior author.

Meta-analysis

MetaDisc version 2 was used to perform the diagnostic test accuracy meta-analysis. We have extracted the sensitivity and specificity from each study, then we have used RevMan calculator version 5.4.1 to calculate the true positive, true negative, false positive, and false negative values. Heterogeneity was assessed using I squared. SROCA curve was also performed for the prediction area. All the results were presented as pooled sensitivity and specificity with 95% confidence intervals (CIs).

Results

Search results

Our initial database search identified a total of 944 records. After removing duplicates, 712 unique articles were available for screening. Following the preliminary screening, 16 studies were selected for full-text evaluation. Of these, 12 met all inclusion criteria and were included in this study [4-10,14-18] Figure 1.

Characteristics of the included studies

Twelve studies were included in our systematic review and meta-analysis. These studies were conducted in different countries such as China, The United States, Turkey, Japan, Spain, Singapore, and Taiwan. Characteristics of

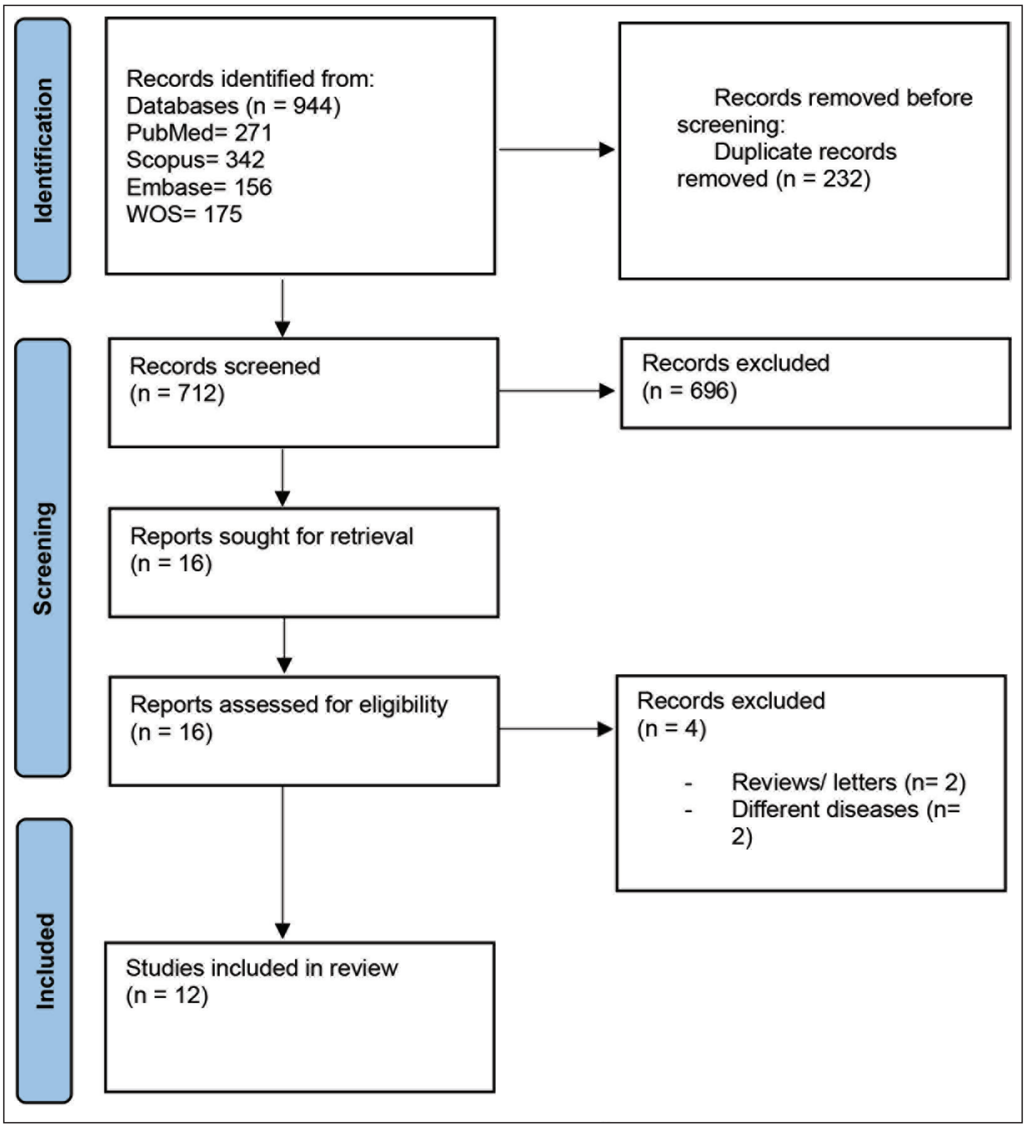

Figure 1. *Flow chart of the selection process.*

the included studies with the main findings of each study are available in Table 1.

Quality assessment

NIH tool was used to assess the quality of the included studies. Out of 12 studies, 8 studies were assessed and considered to have good quality, while 4 studies were assessed and considered to have fair quality. Full details about the assessment process are available in Table S2.

Systematic review and meta-analyses

Identify blepharoptosis

Four studies reported quantitative data about the ability of AI models to predict blepharoptosis before surgery [4,8-10]. The pooled sensitivity and specificity were 83%, 95%CI (0.67, 0.92) and 84%, 95%CI (0.83, 0.86), respectively (Figures 2 and 3). The heterogeneity was high for the sensitivity (I^2 = 98%) and low for the specificity (I^2 = 24%). The area of the 95% prediction ellipse on the

Table 1. *Characteristics of the included studies.*

Study	Country	Population	Number of patients	Aim	Conclusion
Lim et al. [5]	-			Study investigated the capacity of AI models, DALL-E 2, Midjourney, and Blue Willow, to generate realistic images pertinent to cosmetic surgery.	In summary, the horizons of cosmetic surgery are broadening with the advent of AI-generated imagery. This merger promises enriched patient education, more effective counseling, and an enhanced training paradigm. Nevertheless, as with any technological innovation, its adoption should be judicious, ensuring it augments existing methodologies rather than replacing them. The juxtaposition of innovation and ethics in this realm also necessitates rigorous oversight and regular updates.
Lou et al. [7]	China	Patients who underwent blepharoptosis surgery in our oculoplastic clinic between January 2016 and September 2019 were invited to participate in this study.		To propose a novel deep learning-based image analysis to automatically measure eyelid morphological properties before and after blepharoptosis surgery	Conclusion: This technique had high accuracy and repeatability for automatically measuring eyelid morphology, which allows objective assessment of blepharoptosis surgical outcomes. Using only patients' photographs, this technique has great potential in diagnosis and management of other eyelid-related diseases.
Hung et al. [9]	China	Photographs of patients taken by a hand-held digital camera (Canon DIGITAL IXUS 950 IS) at a tertiary oculoplastic clinic of adult patients over 20 years old were retrospectively collected over the past 20 years for surgical evaluation.	782	The aim of this study is to develop an AI model that accurately identifies referable blepharoptosis automatically and to compare the AI model's performance to a group of non-ophthalmic physicians.	The CNN model achieved a sensitivity of 92% and a specificity of 88%, compared with the non-ophthalmic physician group, which achieved a mean sensitivity of 72% and a mean specificity of 82.67%. The AI model showed better performance than the non-ophthalmic physician group in identifying referable blepharoptosis, including true and pseudoptosis, correctly. Therefore, AI-aided tools have the potential to assist in the diagnosis and referral of blepharoptosis for general practitioners.
Qu et al. [17]	China	A total of 64 patients who underwent pouch plastic surgery from January 2020 to March 2021	64	This study is aimed at exploring the impact of eye model based on a multichannel CNN on eye plastic surgery and esthetic effect, thus formulating methods to improve the effect of eye plastic surgery.	The AI model using CNNs achieved better performance than the non-ophthalmic physician group and shows value as a diagnostic tool to be used in assisting the referral of blepharoptosis, including true and pseudoptosis.
Goodyear et al. [6]	US	photographs and clinical information were collected from a database of patients evaluated from January 1998 to January 2020 at the Jules Stein Eye Institute at the University of California,	47,394 images of human faces		Quantify the rejuvenation effect of blepharoplasty.
Abascal Azanza et al. [8]	Spain	This study utilized original photographs collected from a tertiary oculoplastic clinic over a 25-year period, spanning from 1993 to 2018.	2,000 periocular image from 10,555 patients in the database		This study introduces a deep-learning model with CNNs to detect blepharoptosis in more realistic conditions. In this study, we offer a holistic approach to the diagnosis of blepharoptosis using CNNs. Specifically, we utilize images of both eyes, including the eyebrows, and train a single CNN model end-to-end using only pixel values and disorder labels as inputs.

Study	Country	Population	Number of patients	Aim	Conclusion
Bahçeci Şimşek and Şirolu [14]	Turkey	The patient population was selected from an ophthalmology clinic oculoplastic department retrospectively. All patients who underwent standard upper eyelid blepharoplasty surgery with or without Müller's muscle-conjunctival resection (MMCR) by one oculoplastic surgeon (IBS) during the time frame of January 2016-May 2019 were included.All patients who underwent upper eyelid blepharoplasty surgery (Group I), or upper eyelid blepharoplasty with MMCR (Group II) were included. Both pre-operative and 6-month post-operative anterior full-face photographs of 55 patients were analyzed.	55	Purpose to evaluate the post-operative changes with a computer vision algorithm for anterior full-face photographs of patients who have undergone upper eyelid blepharoplasty surgery with, or without, a Müller's muscle-conjunctival resection (MMCR).	Eyelid surgery for esthetic purposes requires artistic judgment and objective evaluation. Because of the slight differences in photograph sizes and dynamic factors of the face due to head movements and facial expressions, it is hard to compare and make a truly objective evaluation of the eyelid operations. With a computer vision algorithm using the face and facial landmark detection system, the photographs are normalized and calibrated. This system offers a simple, standardized, objective, and repeatable method of patient assessment. This can be the first step of AI algorithm to evaluate patients who have undergone eyelid operations.
Khong et al. [16]	US	Total of 94 patients Pre- and post-operative patient blepharoplasty images from inception through December 2023 were extracted from the American Society of Plastic Surgeons website.	94	We investigated the ability of CNNs to assess differences in perceived age before and after blepharoplasty and examined correlations between CNN-generated results and human evaluations.	CNNs quantified reductions in perceived age following blepharoplasty, with results aligning with human evaluations. CNN perceived age reduction was greatest in patients who appeared older than their true age, particularly for those with larger discrepancies. These findings support the potential utility of CNNs as objective tools for assessing esthetic outcomes and may help preoperatively guide patient expectations for post-operative age reduction.
Tabuchi et al. [10]	Japan	We used images of eyelids taken with an iPad mini 5 at Saneikai Tsukazaki Hospital between October 18, 2017, and August 8, 2018.	681	To assess the performance of AI in the automated classification of images taken with a tablet device of patients with blepharoptosis and subjects with normal eyelid	AI was able to classify with high accuracy images of blepharoptosis and normal eyelids taken using a tablet device. Thus, the diagnosis of blepharoptosis with a tablet device is possible at a high level of accuracy.
Tan et al. [15]	Singapore	A retrospective and prospective review of medical records of patients 21 years old and above seen at a tertiary oculoplastic clinic at the Singapore National Eye Centre for the assessment of blepharoptosis, from 2016 to 2022, was performed.	771	To develop and validate a deep-learning model for the detection of functional blepharoptosis from external ocular photographs, and to quantify the impact of augmenting the training data with synthetic images on model performance.	Functional blepharoptosis can be detected from external ocular photographs with high confidence, and the use of synthetic data from generative models has the potential to further improve the model performance.
Sun et al. [18]		This study involved patients undergoing varying types of blepharoptosis operations at our oculoplastic clinic between June 2016 and April 2021	362	To automatically predict the post-operative appearance of blepharoptosis surgeries and evaluate the generated images both objectively and subjectively in a clinical setting.	The fully automatic deep learning-based method can predict post-operative appearance for blepharoptosis surgery with high accuracy and satisfaction, thus offering the patients with blepharoptosis an opportunity to understand the expected change more clearly and to relieve anxiety. In addition, this system could be used to assist patients in selecting surgeons and the recovery phase of daily living, which may offer guidance for inexperienced surgeons as well.
Hung et al. [4]	Taiwan	Full face images, collected as part of the oculoplastic clinic evaluation at a tertiary ophthalmology clinic in Taiwan,	250	Blepharoptosis is a known cause of reversible vision loss. Accurate assessment can be difficult, especially amongst non-specialists. Existing automated techniques disrupt clinical workflow by requiring user input, or placement of reference markers. Neural networks are known to be effective in image classification tasks. We aim to develop an algorithm that can accurately identify blepharoptosis from a clinical photo.	We report the use of AI to accurately diagnose blepharoptosis from a clinical photograph with no external reference markers or user input requirement. Most current-generation CNN architectures performed reasonably on this task, with the DenseNet121, and Resnet18 architectures without pre-training performing best in our dataset.

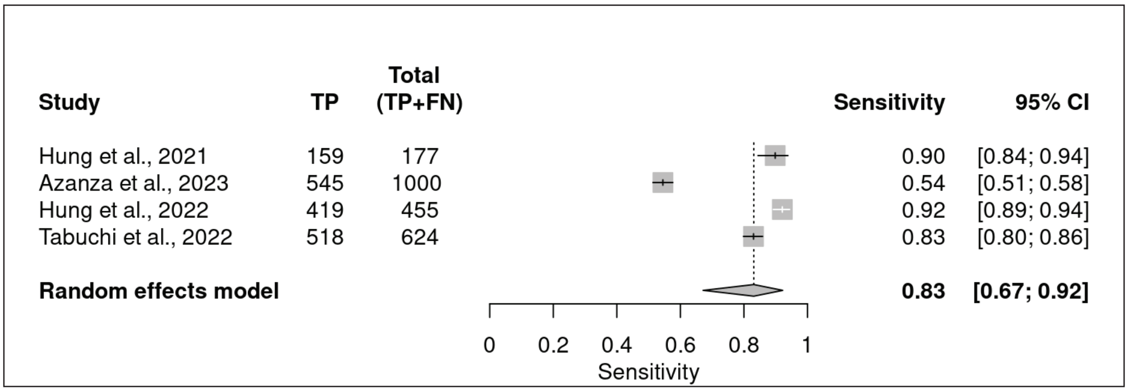

Figure 2. *Pooled meta-analysis of the sensitivity.*

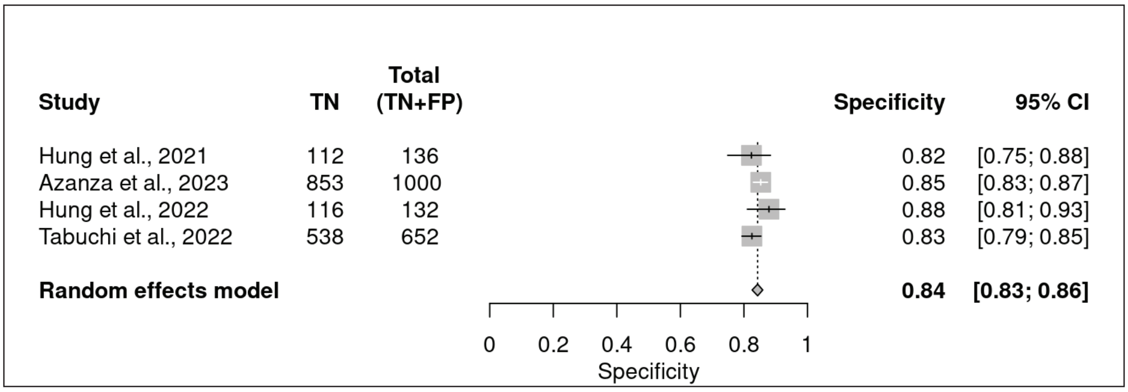

Figure 3. *Pooled meta-analysis of the specificity.*

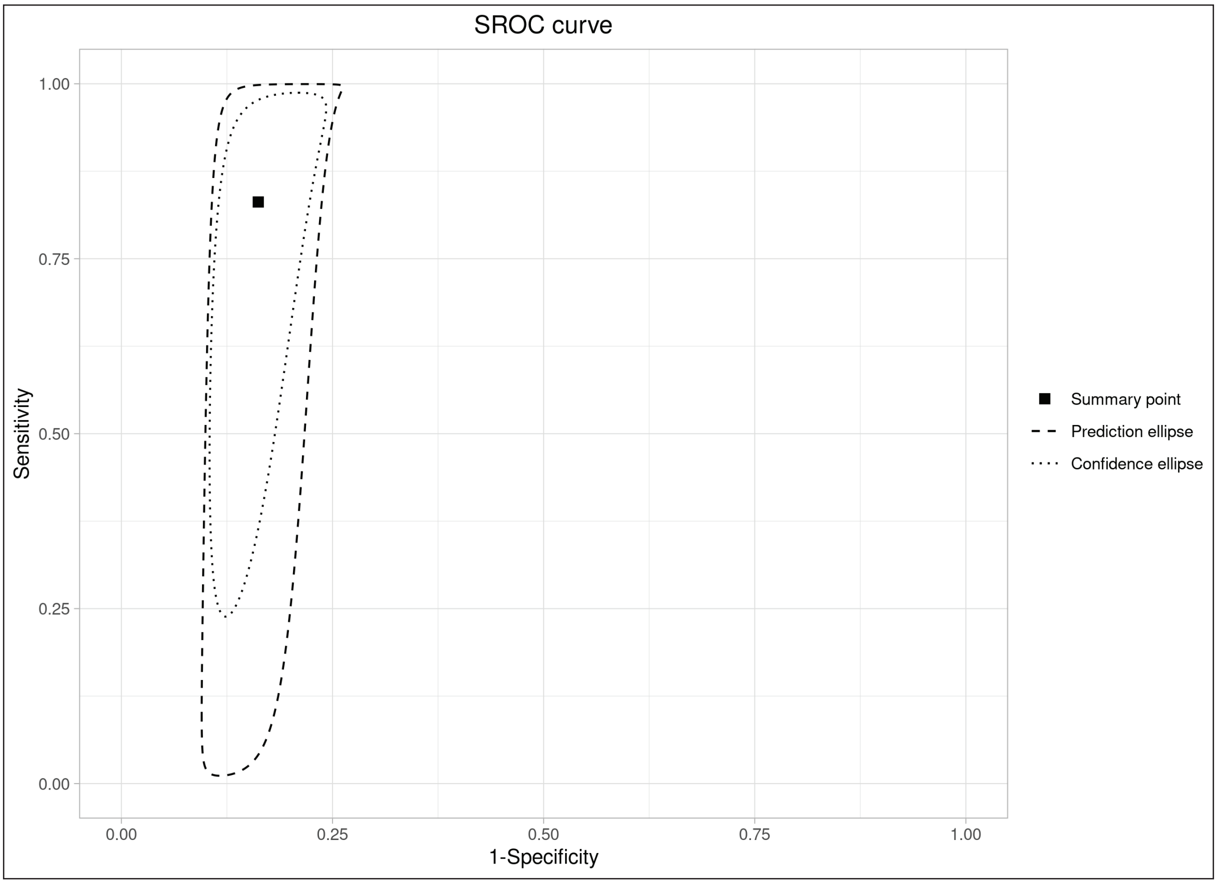

Figure 4. *SROC curve.*

Summary Receiver Operating Characteristic (SROC) curve was 0.111 (Figure 4), representing the expected range of sensitivity and specificity values for future studies on AI-based blepharoptosis detection. Only one study reported the predictive ability of AI models in the post-operative appearance of blepharoptosis surgeries [18].

Quantify perceived age reduction

Two studies reported the role of AI models in quantifying perceived age reduction [6,16]. Goodyear et al. [6] showed that, on average, blepharoplasty provides a reduction effect of 2 years. Khong et al. [16] study showed that age reduction was not associated with gender, true pre-operative age, or procedure type. Also, patients who were perceived by the CNN model to be older than their actual pre-operative age experienced a greater reduction in AI-estimated age after surgery compared to those perceived as younger (a reduction of 5.0 *vs.* 2.3 years) [16].

Eyelid morphology after blepharoptosis surgery

Five studies reported the role of AI in predicting the morphology and esthetic effect of eye plastic surgery patients [5,7,14,15,17]. Qu et al. [17] demonstrated that a multichannel CNN-based eye model enhanced surgical repair and esthetic outcomes while reducing post-operative complications. Lou et al. [7] highlighted the high accuracy and repeatability of AI techniques in objectively measuring eyelid morphology and assessing blepharoptosis outcomes using patient photographs. Similarly, Tan et al. [15] showed that functional blepharoptosis could be confidently detected from external photos, with synthetic data further boosting model performance. Lim et al. [5] emphasized the importance of ethical AI integration, noting the lack of diversity in generated training images and underscoring the need for broader representation to ensure reliable outcomes. Bahçeci Şimşek and Şirolu [14] addressed the challenge of objective assessment due to facial dynamics and image inconsistencies, proposing a computer vision system for facial landmark detection and image normalization, marking a foundational step toward standardized AI-based evaluation in esthetic eyelid procedures.

Discussion

This systematic review and meta-analysis synthesized current evidence on the application of AI and ML in the context of blepharoplasty, with a focus on diagnostic accuracy, esthetic evaluation, and post-operative outcome assessment. About 12 studies met the inclusion criteria and were analyzed in detail. The pooled diagnostic performance of AI models in identifying blepharoptosis preoperatively demonstrated a sensitivity of 83% and a specificity of 84%, indicating a promising role for AI in clinical decision making and surgical planning. In addition, two studies assessed the ability of AI models to quantify perceived age reduction following blepharoplasty. Findings suggested that patients perceived preoperatively as older experienced a greater reduction in AI-estimated post-operative age, with differences reaching up to 5.0 years, compared to 2.3 years in patients perceived as younger. Moreover, five studies evaluated the application of AI in assessing eyelid morphology and esthetic outcomes, highlighting its potential to offer standardized, objective, and reproducible measurements. Collectively, these findings underscore the emerging utility of AI in enhancing diagnostic accuracy, optimizing esthetic evaluations, and supporting evidence-based practices in blepharoplasty.

The diagnostic performance of AI models in detecting blepharoptosis, as evidenced by our pooled sensitivity of 83% and specificity of 84%, aligns closely with emerging external studies. For example, a deep-learning model using MobileNetV2 achieved nearly identical metrics: 83% sensitivity, 82.5% specificity, and area under the curve of 0.90, based on tablet-derived eyelid images in a prospective study of 1,276 photos [10]. In addition, Hung et al. [4] reported comparable results, with 92% sensitivity and 88% specificity using AI to classify clinical photographs. In the realm of esthetic outcomes, AI-based age estimation models have also been independently validated. A study assessing lower blepharoplasty outcomes in 150 patients using multiple CNN platforms, including Amazon Rekognition and Microsoft Azure Face, found an average perceived age reduction of approximately 2 years, with male patients exhibiting slightly greater rejuvenation [19]. Another investigation using a British deep learning algorithm confirmed similar results, noting significant age reduction across gender- and procedure-specific subgroups [6]. These parallel observations demonstrate that our results are not isolated and suggest that AI-driven age estimation may become a valuable adjunct for objective outcome quantification and patient counseling.

The integration of AI in blepharoplasty holds significant clinical promise. In the pre-operative phase, AI-based diagnostic tools can facilitate objective assessments of ptosis, support personalized surgical planning, and enhance patient counseling by visualizing potential outcomes and providing data-driven prognoses [4]. CNN-estimated age reduction metrics, for example, may aid surgeons in managing esthetic expectations and in quantifying rejuvenation benefits in a standardized way [6]. Postoperatively, AI models can be leveraged to monitor outcomes with greater consistency, reducing reliance on subjective interpretation, and enabling longitudinal tracking of surgical efficacy [18]. These tools also offer the potential for real-time feedback, enabling earlier detection of suboptimal outcomes or complications.

Despite its promise, the application of AI in blepharoplasty is not without technical and ethical challenges. A critical limitation remains the lack of standardized, high quality, and demographically diverse training datasets. Many AI models are trained on images that predominantly feature young, light skinned, female faces, which limits their applicability across diverse patient populations and contributes to diagnostic inaccuracies in underrepresented groups. Furthermore, variability in image acquisition, such as differences in lighting, head position, and facial expression, can significantly affect model performance and reproducibility. Transparency in model development, including open-access datasets and explainable algorithms, is essential for clinical validation and trust. Ethically, the use of facial recognition and image-based data demands stringent adherence to patient privacy standards. Informed consent, data encryption, and strict regulatory oversight must be foundational components of any AI-driven tool used in clinical practice to prevent misuse and protect patient confidentiality.

This study has several limitations that should be acknowledged. First, the number of eligible studies included in the meta-analysis was relatively small. Second, significant heterogeneity was observed in the sensitivity estimates for detection of blepharoptosis, which could be attributed to variations in AI model architectures, training datasets, image acquisition protocols, and patient populations across studies. Third, all included studies were observational in nature and varied in quality, with four studies rated as fair quality based on the NIH tool. Fourth, there was a lack of standardized reporting metrics and validation methods across the included studies.

Conclusion

This systematic review and meta-analysis highlight the promising role of AI in enhancing diagnostic accuracy, esthetic evaluation, and surgical outcome assessment in blepharoplasty. Despite existing limitations, AI shows potential to support clinical decision making, promote objective evaluation, and improve patient satisfaction through personalized, data-driven approaches in oculoplastic surgery.

List of Abbreviations

AI	Artificial intelligence
AUC	Area under the curve
CI	Confidence interval
CNN	Convolutional neural network
GAN	Generative adversarial network
I^2	I-squared (heterogeneity statistic)
ML	Machine learning
MRD	Margin reflex distance
MRD1	Margin reflex distance 1
MRD2	Margin reflex distance 2
NIH	National Institutes of Health
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SROC	Summary receiver operating characteristic

Acknowledgments

None.

Conflict of interest

The authors declare no competing financial interests.

Funding

None.

Consent to participate

Not applicable.

Ethical approval

Not applicable.

Data availability statement

The data generated in this study are available upon request from the corresponding author.

Author details

Abdulrhman Abdulaziz Alnoshan[1], Yousef Mesaed Al-Shammari[2], Abdulelah Abdullaha A. Alanazi[3], Noura almarri[4], Jaber Ali Alharbi[5], Fay Abdulrahman Hamad Alshalan[6], Walaa Fahad Almutawa[1], Mohammed Ahmed Ali Argabi[7], Lojain Mohammed A Maawadh[8], Abdullah Altamimi[9]

1. College of Medicine, King Saud University, Riyadh, Saudi Arabia
2. Ophthalmology Assistant, Al-Bahar Eye Center, Kuwait City, Kuwait
3. Faculty of Medicine, Northern Border University, Arar, Saudi Arabia
4. Faculty of Medicine, Kuwait University, Kuwait City Kuwait
5. Faculty of Medicine, Qassim University, Buraydah, Saudi Arabia
6. Department of Optometry and Vision Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia
7. Faculty of Medicine, King Khalid University, Abha, Saudi Arabia
8. College of Medicine, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia
9. Pediatric Emergency and Medical Toxicology, King Fahad Medical City, Riyadh, Saudi Arabia

Supplementary content (If any) is available online.

References

1. Esteva A, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM, et al. Dermatologist-level classification of skin cancer with deep neural networks. Nature. 2017;542(7639):115–8. https://doi.org/10.1038/nature21056
2. Kermany DS, Goldbaum M, Cai W, Valentim CCS, Liang H, Baxter SL, et al. Identifying medical diagnoses and treatable diseases by image-based deep learning. Cell. 2018;172(5):1122–31. https://doi.org/10.1016/j.cell.2018.02.010
3. Poplin R, Varadarajan AV, Blumer K, Liu Y, Mcconnell MV, Corrado GS, et al. Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning. Nat Biomed Eng. 2018;2(3):158–64. https://doi.org/10.1038/s41551-018-0195-0
4. Hung JY, Perera C, Chen KW, Myung D, Chiu HK, Fuh CS, et al. A deep learning approach to identify blepharoptosis by convolutional neural networks. Int J Med Inf. 2021;148:104402. https://doi.org/10.1016/j.ijmedinf.2021.104402
5. Lim B, Seth I, Kah S, Sofiadellis F, Ross RJ, Rozen WM, et al. Using generative artificial intelligence tools in cosmetic surgery: a study on rhinoplasty, facelifts, and blepharoplasty procedures. J Clin Med. 2023;12(20):6524. https://doi.org/10.3390/jcm12206524
6. Goodyear K, Saffari PS, Esfandiari M, Baugh S, Rootman DB, Karlin JN. Estimating apparent age using artificial intelligence: quantifying the effect of blepharoplasty. J Plast Reconstr Aesthet Surg. 2023;85:336–43. https://doi.org/10.1016/j.bjps.2023.07.017
7. Lou L, Cao J, Wang Y, Gao Z, Jin K, Xu Z, et al. Deep learning-based image analysis for automated measurement of eyelid morphology before and after blepharoptosis

surgery. Ann Med. 2021;53(1):2278–85. https://doi.org/10.1080/07853890.2021.2009127

8. Abascal Azanza C, Barrio-Barrio J, Ramos Cejudo J, Ybarra Arróspide B, Devoto MH. Development and validation of a convolutional neural network to identify blepharoptosis. Sci Rep. 2023;13(1):17585. https://doi.org/10.1038/s41598-023-44686-3

9. Nallabothula MP, Aleem A, Setabutr P, Hallak J, Yi D. AutoPtosis: a dual model system for rapid and automatic detection of ptosis. Invest Ophthalmol Vis Sci. 2021;62(8):2759.

10. Tabuchi H, Nagasato D, Masumoto H, Tanabe M, Ishitobi N, Ochi H, et al. Developing an iOS application that uses machine learning for the automated diagnosis of blepharoptosis. Graefe's Arch For Clin Exp Ophthalmol. 2022;260(4):1329–35. https://doi.org/10.1007/s00417-021-05475-8

11. Chartier C, Watt A, Lin O, Chandawarkar A, Lee J, Hall-Findlay E. BreastGAN: artificial intelligence-enabled breast augmentation simulation. Aesthet Surg J Open Forum. 2022. https://doi.org/10.1093/asjof/ojab052

12. Celi LA, Cellini J, Charpignon ML, Dee EC, Dernoncourt F, Eber R, et al. Sources of bias in artificial intelligence that perpetuate healthcare disparities-a global review. PLoS Digit Health. 2022;1(3):22. https://doi.org/10.1371/journal.pdig.0000022

13. Nallabothula MP, Aleem A, Setabutr P, Hallak J, Yi D. AutoPtosis: a dual model system for rapid and automatic detection of ptosis. ARVO Annual Meeting Abstract. 2021;62(8).

14. Bahçeci Şimşek I, Şirolu C. Analysis of surgical outcome after upper eyelid surgery by computer vision algorithm using face and facial landmark detection. Graefes Arch Clin Exp Ophthalmol. 2021;259(10):3119–25. https://doi.org/10.1007/s00417-021-05219-8

15. Tan L, Lim G, Leong YY, Elangovan K, Ting D, Chan AS, et al. Functional blepharoptosis screening with generative augmented deep learning from external ocular photography. Orbit. 2025;44(6):1–7. https://doi.org/10.1080/01676830.2025.2497460

16. Khong J, Davis AJ, Wei O, Cooney CM, Broderick KP. Using facial recognition software to quantify perceived age reduction in patients undergoing blepharoplasty. Ann Plast Surg. 2025;94(4S):S353–358. https://doi.org/10.1097/SAP.0000000000004319

17. Qu Y, Lin B, Li S, Lin X, Mao Z, Li X, et al. Effect of multichannel convolutional neural network-based model on the repair and aesthetic effect of eye plastic surgery patients. Comput Math Methods Med. 2022;2022:1–8. https://doi.org/10.1155/2022/5315146

18. Sun Y, Huang X, Zhang Q, Lee SY, Wang Y, Jin K, et al. A fully automatic postoperative appearance prediction system for blepharoptosis surgery with image-based deep learning. Ophthalmol Sci. 2022;2(3):100169. https://doi.org/10.1016/j.xops.2022.100169

19. Chiou TW, Yen CI, Hsiao YC, Chen HC. AI prediction for post-lower blepharoplasty age reduction. Aesthet Surg J. 2024;44(12):NP922–30. https://doi.org/10.1093/asj/sjae182