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From pixels to precision: Imaging technologies shaping oculofacial plastic surgery practice

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Abstract:

Recent advances in imaging technologies have transformed surgical practice, enabling more accurate diagnoses, refined perioperative planning, and improved patient outcomes. In oculofacial plastic surgery, these tools provide safer and more precise alternatives to traditional approaches, which often relied on invasive exploration or standard imaging with limited accuracy. This review summarizes the current state of imaging technologies in oculofacial plastic surgery and discusses their benefits, limitations, and challenges. Key developments include: (i) Endoscopic imaging, providing high-resolution, magnified visualization for minimally invasive procedures, particularly in lacrimal and orbital surgery, (ii) Exoscopic imaging, a 4K-three-dimensional (3D) external system enhancing precision and team collaboration in microsurgery, (iii) Magnetic resonance imaging offering detailed 3D images of internal structures, with emerging 7T systems providing higher resolution and improved tissue contrast, (iv) Stereotactic navigation, integrating preoperative imaging with real-time tracking to guide complex orbital procedures and fracture repairs, (v) Artificial intelligence-based imaging tools, including machine learning models for disease detection, surgical planning, and outcome prediction, as well as text-to-image systems for preoperative patient counseling. Together, these technologies reduce operative risk, improve functional and esthetic outcomes, and enable patient-specific approaches. Despite challenges such as cost, accessibility, technical limitations, and learning curves, the integration of advanced imaging is steering oculofacial plastic surgery toward minimally invasive, data-driven, and patient-centered practice.

Keywords:

Artificial intelligence, endoscopic imaging, exoscopic imaging, imaging, lacrimal system, magnetic resonance imaging 7T, ophthalmic plastic surgery, orbital surgery, stereotactic navigation

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Introduction

Advances in surgical imaging have revolutionized clinical practice by improving diagnostic precision, perioperative planning, and patient outcomes. Integrating novel imaging modalities, from high-resolution cross-sectional techniques to real-time intraoperative visualization tools, has transformed how surgeons assess anatomy, pathology, and treatment response.[1-3] Preoperative imaging now plays a critical role in risk stratification and surgical planning,[4-6] while intraoperative imaging technologies enhance surgical precision and reduce complications.[7-9] Postoperatively, imaging can monitor recovery, detect complications at an early stage, and evaluate long-term treatment efficacy.[10]

In oculofacial plastic surgery, modern imaging approaches enable enhanced anatomical assessment and optimized surgical planning, with improved safety and accuracy.[11] Previously, surgeons relied on invasive exploration or conventional imaging techniques, which provided limited spatial resolution for complex

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orbital and periocular anatomy and often necessitated more extensive procedures.[12] Recent innovations, including endoscopic and exoscopic imaging,[13] 7T magnetic resonance imaging (MRI), stereotactic navigation,[14,15] and artificial intelligence (AI)-based imaging processing tools,[16] are transforming the field. By enabling patient-specific strategies, these technologies minimize operative risk and enhance both functional and esthetic outcomes. Despite costs, accessibility, and training challenges, advanced imaging is driving oculofacial plastic surgery toward minimally invasive, data-driven practices that prioritize safety, precision, and patient outcomes. This review summarizes recent advances in imaging technologies in oculofacial plastic surgery and highlights their challenges and limitations.

Overview of Oculoplastic Surgeries

Orbital surgeries

Orbital surgery spans orbital decompression surgeries, fracture repairs, tumor excisions, and reconstructions with grafts or implants. The goals are to preserve vision, restore ocular motility, and re-establish orbital volume and contour.

Orbital decompression surgery is performed most often for thyroid eye disease (TED), particularly in cases with dysthyroid optic neuropathy.[17,18] However, it can be performed in other conditions associated with proptosis and subsequent optic neuropathy. The objectives are to reduce exophthalmos and relieve optic nerve compression. Risks include new or worsened diplopia, infraorbital hypoesthesia, hemorrhage, and cerebrospinal fluid leak.[19]

Orbital fractures, including isolated floor or medial wall injuries as well as zygomaticomaxillary complex (ZMC) fractures, present unique challenges because complex three-dimensional (3D) anatomy must be restored through limited exposures.[20] Orbital tumor excision seeks complete removal of benign or malignant lesions while preserving critical structures. Orbital reconstruction restores orbital volume, symmetry, and function after trauma, tumor removal, or congenital defects, using autologous grafts such as bone or cartilage or alloplastic implants, including porous polyethylene or titanium.[21] Common risks across these procedures include inadequate reduction or malposition, impaired ocular motility, sensory deficits, contour deformity, infection, and implant extrusion.[22-24]

Across these procedures, orbital complexity and limitations in traditional techniques highlight the need for innovations that enhance precision, safety, and outcomes.

Nasolacrimal duct surgeries

Nasolacrimal surgery addresses conditions ranging from common nasolacrimal duct obstruction to lacrimal sac tumors. The most performed procedure, dacryocystorhinostomy (DCR), creates a direct anastomosis between the lacrimal sac and nasal cavity and can be performed externally or endonasally. External DCR offers high success rates but leaves a cutaneous scar, whereas endonasal DCR avoids external incisions and allows faster recovery. However, endonasal DCR requires specialized equipment and expertise. Canalicular obstruction or failed DCR may require adjunctive procedures such as conjunctivodacryocystorhinostomy with Jones tube placement. Challenges in nasolacrimal surgery include intraoperative bleeding, restenosis of the osteotomy site, and persistent tearing despite anatomically successful surgery. Endoscopic imaging, intraoperative navigation, and adjunctive stents or lasers have improved visualization and outcomes, but long-term success depends on patient anatomy, surgical technique, and meticulous postoperative care.

Eyelid surgeries

Eyelid surgery includes functional and aesthetic procedures that correct eyelid malpositions, restore periocular function, and improve cosmesis. Functional interventions include ptosis repair, entropion and ectropion correction, and reconstruction after trauma, tumor excision, or congenital anomalies. Esthetic procedures, particularly blepharoplasty, are among the most frequently performed oculoplastic surgeries worldwide, with over one million cases annually.[25] Despite high success rates, complications such as over- or under-correction, asymmetry, lagophthalmos, and dry eye symptoms can affect patient satisfaction. High-resolution photography, 3D facial analysis, and intraoperative guidance are increasingly being applied to eyelid surgery, allowing for more precise assessment of eyelid dynamics, individualized treatment planning, and improved postoperative outcomes.

Advances in Imaging Technologies for Oculofacial Plastic Surgery Interventions

Endoscopic imaging enables precise, minimally invasive management of orbital and lacrimal disorders

An endoscope is a slender tubular instrument that provides real-time visualization of internal anatomical structures. Endoscopic imaging can provide magnified, high-resolution visualization of orbital, lacrimal, and periocular structures, enabling precise, minimally invasive diagnosis and surgery with minimal tissue disruption. Applications include dacryoendoscopy, endoscopic dacryocystorhinostomy (EDCR), orbital endoscopy, endoscopic-assisted orbital fracture repair, and cosmetic procedures such as endoscopic brow and midface lifts.

Dacryoendoscopy is a specialized microendoscopic technique for direct visualization of the lacrimal drainage system (LDS). The scope is advanced through the punctum into the lacrimal sac and duct, with saline irrigation or controlled air insufflation used to clear debris.[26] Advances in instrumentation have driven its development: Modern rigid microendoscopes (diameter 0.9–1.1 mm) provide up to 15,000-pixel resolution with a depth of focus from 1.5 to 7 mm, and incorporate ports for therapeutic interventions.[27-29] Dacryoendoscopy not only enables diagnostic visualization of the LDS but also serves as a minimally invasive therapeutic platform, allowing direct or sheath-guided probing, intubation, and the use of lasers, microdrills, or hollow trephines for obstruction management and dacryoplasty [Table 1].[30,31]

Probes or outer sheaths facilitate dacryoendoscope entry into the LDS, provide irrigation, and protect the scope tip. Reported probe characteristics include lengths of 50–60 mm, outer diameters of 0.7–0.9 mm, fields of view of 65°–70°, 5000–10,000 image elements, observation depths of 5–10 mm, and bending angles of 0°–27°.[31] Modern designs enhance maneuverability through different probe types: Bent probes (upward 27° at 10 mm) are standard in Japanese practice, straight probes (0°), which are mainly manufactured in Germany are suited for posteriorly sloping ducts, and double-bent probes allow full visualization in patients with prominent brow anatomy.[28] Custom sheaths, such as modified intravenous catheters, can additionally serve for high-pressure irrigation or biopsy. Dacryoendoscopes are illuminated by cold light sources, typically xenon, with images transmitted to charge-coupled device or high-definition 3-chip camera systems.[30]

Table 1: Indications, contraindications, and limitations of dacryoendoscopy[23,25]

Category	Indications/considerations
Diagnostic	Localize/differentiate obstruction, stenosis, edema; assess CNLDO, canalicular disorders, lacrimal sac/NLD stenosis or adhesions; detect tumors and foreign bodies; monitor postprocedure changes
Therapeutic	Recanalization of NLD/canaliculi; dacryolith/concretion removal; dacryoendoscopy-assisted probing; guided intubation; intralesional injections; fracture reduction
General use	Focal/segmental NLD obstruction, canalicular stenosis, dacryoliths; minimally invasive alternative to DCR
Absolute contraindications	Acute dacryocystitis; bleeding disorders; proximal canalicular obstruction
Technical limitations	Cannot treat bony obstructions or long stenotic segments; poor visualization in severe stenosis; limited anatomical context, may require CT/MRI; black lesions (e.g., melanomas) may appear gray
Procedural risks	Mucosal laceration, incorrect intubation, canalicular cheese wiring, granulation tissue; infection; tube-related issues
Other limitations	High cost; steep learning curve; lower long-term success than DCR; limited long-term outcome data

DCR=Dacryocystorhinostomy, NLD=Nasolacrimal duct, CT=Computed Tomography, MRI=Magnetic Resonance Imaging, CNLDO=Congenital nasolacrimal duct obstruction

Complementing endoscopic techniques, advanced piezoelectric devices allow precise bone dissection while sparing adjacent soft tissues by relying on high-frequency ultrasonic vibrations.[32] It has gained increasing interest in surgical fields such as maxillofacial,[32,33] craniofacial,[34] and orbital surgery,[35,36] where delicate anatomical structures require safe and controlled manipulation. In contrast to conventional rotary instruments or oscillating saws, the specific ultrasonic frequencies of piezoelectric devices allow for selective and precise cutting while preventing damage to surrounding tissues, as well as improving patient outcome and recovery.[37] Furthermore, numerous advantages of the piezoelectric surgery tool exist, such as reduced trauma to soft tissue, curvilinear cutting, no thermal damage, reduced risk of hemorrhage, sterile irrigation, and excellent visibility within the surgical field due to negligible bleeding combined with effective irrigation and high luminosity by Light Emitting Diode (LED) lights.[32]

Advances in optical design and imaging have not only refined dacryoendoscopy but also redefined related procedures such as EDCR, orbital endoscopy, orbital fracture repair, and cosmetic interventions. High-definition endoscopes, angled optics, 3D visualization, and intraoperative navigation enable millimetric precision, safer osteotomy and fracture reduction, and improved visualization of mucosal, vascular, and orbital structures. In EDCR, these technologies allow precise osteotomy planning and enhanced mucosal management, while orbital endoscopy facilitates decompression, biopsy, and foreign body removal through minimally invasive access.[38,39] Similarly, endoscopic-assisted brow and midface lifts, such as the endoscopic gliding forehead lift, use small incisions (approximately 3 cm along the anterior hairline and 2.5 cm at the sideburn), with no temporal incision, minimizing tissue disruption and visible scarring.[40] These approaches preserve muscle function, allow precise skin mobilization and fixation, and reduce recovery time.[41] Together, these innovations exemplify the shift in oculofacial plastic surgery from simple visualization to image-augmented precision surgery.

Exoscopic imaging provides high-definition three-dimensional views of the orbit, enhancing precision and ergonomics in orbital surgery

An exoscope is an advanced high-definition 4K-3D external imaging system designed for microsurgical procedures, providing a magnified view of the operative field on a large 3D monitor [Figure 1].[42] For instance, the ORBEYE™ 3D exoscope system (Olympus, Tokyo, Japan, or Sony Olympus Medical Solutions Inc., Tokyo, Japan) utilizes a 55-inch 3D screen.[43] Similarly, the VITOM® system (Karl Storz Endoscopy GmbH, Tuttlingen, Germany) uses a 0° telescope with an HD camera and Xenon-300W illumination, displaying images with ×2–16 magnification on multiple monitors, including a wireless option for teaching.[44] Unlike endoscopes, the exoscope's camera remains external to the patient, positioned above the surgical site, and projects real-time high-resolution images onto a display.[42,45] This configuration allows the entire surgical team to share the same operative view, enhancing situational awareness, collaboration, and intraoperative education.

In orbital surgery, exoscopes offer exceptional optical capabilities, including high-definition magnification and precise visualization of fine anatomical structures, which is particularly valuable in narrow or deep operative fields.[42] The system typically employs a 4K-3D orbital camera mounted on a semi-robotic flexible arm, with integrated LED illumination and an ultrafast image processor to ensure optimal lighting and image clarity.[43,45] Large medical-grade 3D monitors, viewed with polarized glasses, provide immersive visualization for the surgeon and the team, while high optical and digital zoom allow detailed inspection of delicate tissues, fracture lines, and neurovascular structures.[46,47]

Exoscopes have been successfully applied in orbital fracture reduction, facilitating subciliary or transconjunctival approaches by improving visibility in confined spaces, enabling precise plate placement, reducing operative time, and enhancing ergonomics and teamwork.[42] In orbital cavernous hemangioma removal via transpalpebral approaches, they provide high-definition magnification and detailed anatomical resolution.[45] While the exoscope itself does not directly minimize ocular globe retraction, its integration with intraoperative navigation and ultrasound can limit retraction on the ocular globe.[45] Integration with intraoperative navigation and ultrasound allows real-time lesion localization without interrupting the main surgical view, often using Picture-in-Picture display modes.[45] In hybrid exo-endoscopic lateral orbital wall procedures, exoscopes provide safe surgical corridors, support multihand techniques, and enable precise management of highly vascular or complex orbital lesions, enhancing precision, safety, and surgeon performance.[46]

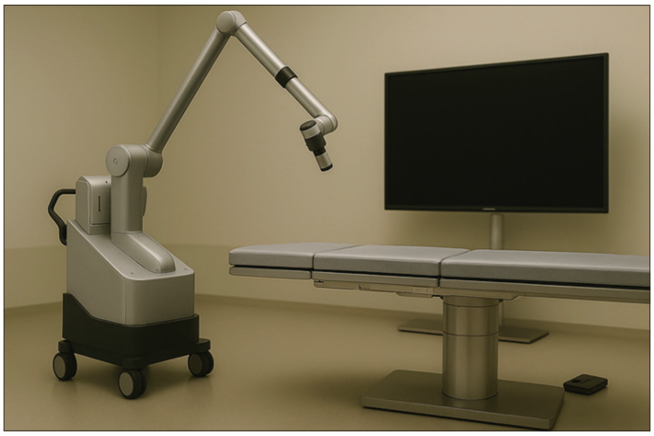

Figure 1: Artificial intelligence-generated image of an exoscope system. An exoscope system encompasses a high-resolution camera and telescope, in which the system projects the recorded image onto at least one monitor. OpenAI. (2025). ChatGPT 4.o.

Magnetic resonance imaging, from 1.5T to emerging 7T, enables high-resolution orbital and lacrimal drainage system imaging

MRI is a noninvasive technique that produces high-resolution, 3D images of internal anatomy. MRI scanners generate strong magnetic fields to align the axes of spinning hydrogen nuclei, which are abundant in water and soft tissues in the body.[48] When radiofrequency pulses are applied, these nuclei are briefly displaced from alignment and, as they return to their resting state, emit signals that are captured by receiver coils and reconstructed into detailed images. The rate at which the nuclei relax varies by tissue type, producing two main measurements: T1 relaxation, which reflects the time for the magnetic vector to realign with the main field, and T2 relaxation, which reflects the return of axial spin to equilibrium. Different tissues can therefore be distinguished based on these relaxation properties. Specific pulse sequences can further enhance visualization: Fat-suppression sequences remove the signal from fat to highlight underlying abnormalities, and contrast-enhanced sequences increase the visibility of vascularized lesions. The MRI field strength can vary, typically ranging from 0.5 tesla (T) to 3T in clinical practice. A major advancement is the 7T MRI system, approved by the FDA in 2017, which provides ultra-high-resolution images and improved tissue contrast, previously limited to research settings.[49] Compared with 1.5T and 3T, 7T MRI offers higher signal- and contrast-to-noise ratios, smaller voxel sizes, and stronger susceptibility contrast, enhancing lesion conspicuity, detection, and characterization.[50]

Building on these principles, orbital MRI is typically performed at 1.5T or 3T. While 1.5T offers adequate diagnostic quality, 3T enables higher-resolution imaging with shorter scan times.[51] Regarding receiver coils, standard head coils are usually sufficient for general orbital imaging, whereas surface coils (pad-like devices placed directly over the orbits) offer enhanced resolution for detailed assessment of the globe and anterior orbital structures. Standard orbital MRI sequences include T1-, T2-, fat-suppressed, and contrast-enhanced scans tailored to evaluate the globe, optic nerves, extraocular muscles, lacrimal gland, orbital fat, and surrounding soft tissues. Diffusion-weighted imaging can further aid in differentiating highly cellular orbital tumors, such as lymphomas, from abscesses or inflammatory lesions.

MR dacryocystography (MRD) is a specialized orbital MRI protocol, increasingly favored for evaluating the LDS due to its high soft-tissue contrast and non-invasive nature.[52,53] It can be performed with or without gadolinium, and dynamic MR sequences such as time-resolved angiography with interleaved stochastic trajectories or 3D spoiled gradient allow real-time visualization of tear flow. Noncontrast MRD uses heavily T2-weighted sequences to highlight static or slowly moving fluid without punctal injection and can be combined with standard orbital MRI to assess surrounding periorbital tissues. By comparison, traditional dacryocystography and computed tomography (CT)-based techniques can localize obstructions but involve radiation exposure, require canalicular cannulation, and provide limited soft-tissue detail, while dacryoscintigraphy offers functional assessment of tear outflow.[54,55]

Experimental 7T MRI provides ultra-high-resolution images with microstructural detail, offering potential benefits for preoperative planning and precision-guided oculofacial interventions.[56] In the orbit, 7T MRI has shown improved delineation of lesions, with better visualization of margins and internal structures.[50] For example, internal microvessels were visible in 43% of lesions at 7T but not at 3T.[57] Dedicated multichannel eye coils enable optimized anatomic imaging with minimal artifacts and spatial resolution as fine as 0.2 mm × 0.2 mm × 1.0 mm for 3D gradient echo sequences.[58,59] Beyond lesions, 7T MRI provides detailed lacrimal-gland imaging, allowing study of tissue architecture and the isthmus, which can inform 3D bioprinting of scaffolds and targeted therapies.[60] Quantitative imaging of extraocular muscles is also feasible, permitting measurement of fat fractions and muscle volumes in conditions such as myasthenia gravis and Graves' orbitopathy, despite their small size and susceptibility to motion artifacts.[61] While 1.5T and 3T MRI remain standard, 7T studies highlight the potential for improved orbital imaging, though further research with larger cohorts is needed.[57]

Stereotactic navigation enables precise, real-time three-dimensional guidance in complex orbital surgery

Stereotactic navigation has been significantly employed in complex orbital surgical procedures, given the ability to visualize in real-time 3D structures and to navigate through anatomical structures with high precision and accuracy.[62,63]

While using stereotactic navigation in orbital surgeries, six main steps have to be successfully completed [Figure 2].[64] In the context of stereotactic-guided navigation, specific parameters must be respected: Contiguous thin sections (<1 mm) must be obtained from the vertex to the hard palate with no gantry tilt. The patient's head must be in a neutral position during CT scan acquisition. If 3D visualization of the orbit is required (i.e., in complex

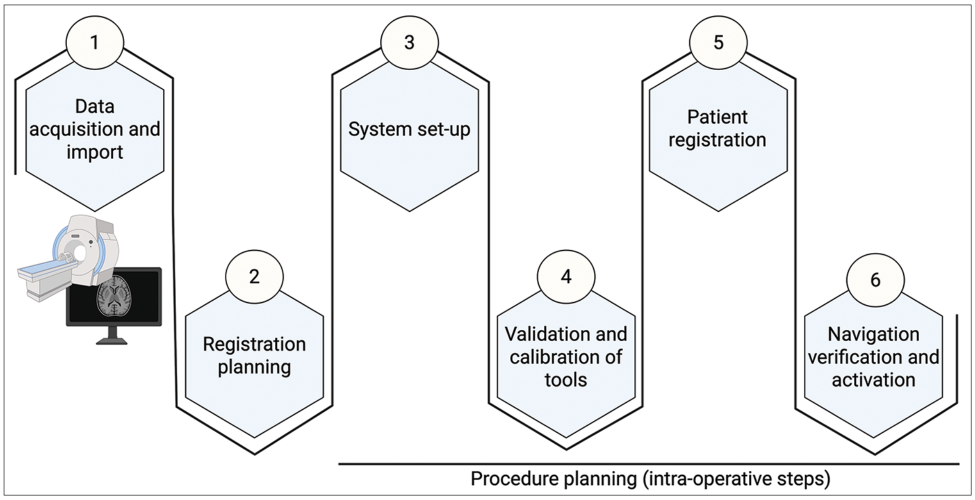

Figure 2: Flow chart of stereotactic navigation steps. Prior to performing a surgical case under stereotactic navigation, six main steps need to be achieved. Patients must undergo computed tomography or magnetic resonance imaging scans and have their data imported in the digital imaging and communications in medicine database. The registration planning is the most crucial step and aims to correlate patient anatomy with obtained imaging data. Intra-operative steps (step 3 to step 6) are required to enable the system. Created in BioRender. Kulbay, M. (2025) https://BioRender.com/9rcjr7x

tumor resection), the craniomaxillofacial software can be selected to enable virtual planning, including automatic orbital segmentation and surgical simulation.

Registration is the most crucial step, aligning patient anatomy with CT scan images on the navigation platform. It is performed by using soft-tissue surface anatomy or bony landmarks (i.e., fiducial screw) with or without the markers [Table 2]. Several software options exist, though most oculofacial plastic surgeons prefer soft-tissue surface anatomy registration since the forehead's soft tissue remains stable during surgery. Regardless of method, a 1 mm registration error in the periorbital region is considered acceptable but may increase with periorbital edema. Validation is done using the orbital rim and canthi before surgery. However, virtual registration is more complex in severe traumas, given anatomical structure loss and increased bone fragmentation.[65]

Intraoperative tracking is achieved with electromagnetic or optical guidance. Electromagnetic guidance is less invasive, using a dynamic reference frame secured to the patient's forehead with a plaster, whereas optical systems require a tracker fixed to the skull with screws.[64] Table 3 summarizes the advantages and disadvantages of both techniques.

Advanced applications of stereotactic navigation have further optimized orbital fracture reconstruction.[66] Virtual mirroring of the intact contralateral orbit enables restoration of orbital symmetry and accurate defect modeling.[67] Image fusion of preoperative and intraoperative datasets facilitates intraoperative validation of implant positioning and orbital volume restoration.[68] The use of stereolithography files, a standard format for 3D surface geometry, permits export of patient-specific orbital reconstructions for 3D printing of anatomical models, prebending templates, or patient-specific implants.[69] Intraoperative navigation additionally allows for real-time assessment of implant placement, reducing the risk of malposition and secondary revision procedures.

Table 2: Comparison of the soft tissue surface anatomy versus skeletal bony landmarks for registration step in stereotactic navigation systems[64]

	Advantages	Disadvantages
Soft tissue surface anatomy registration	More accurate given the acquisition of 200 points	Less accurate when soft tissue movement is involved
Skeletal bony registration		Less accurate given 4 to 5 points

Table 3: Head-to-head comparison of electromagnetic versus optical based tracking systems in stereotactic navigation[64]

	Advantages	Disadvantages
Electromagnetic tracking system	Noninvasive tracker set up	Less accurate
	Low cost	Narrow field
	No line-of-sight interference	Interference with ferromagnetic instruments
	Adequate surface registration	
Optical tracking system	Greater accuracy	Greater cost
	Larger field	Line-of-sight interference present
		Pinning of skull required

Stereotactic navigation enhances precision and outcomes in oculofacial surgery. It does not prolong surgical time in orbital decompression surgery[14] or posterior orbital tumor surgery[70] and results in greater proptosis reduction.[14,71] Its impact on surgical time remains debated: One prior retrospective study reported shorter surgical times in patients with TED undergoing unilateral navigation-guided orbital decompression,[72] while another found times longer by 40 min in a similar cohort in France.[71] Navigation-guided orbital decompression surgery also reduces the need for corrective strabismus surgery,[72] and lower revision rates in posterior orbital tumor resection.[70] It facilitates maximal lateral orbital wall decompression, with dura exposure through smaller surgical incisions.[73] In displaced and comminuted ZMC fractures, stereotactic navigation allows accurate reconstruction,[65] with errors of <1 mm compared to preoperative CT scans.[74]

Overall, the improved surgical accuracy with stereotactic-guided navigation outweighs the potential drawback of longer operative times.

Artificial intelligence-based imaging processing tools support diagnosis, assessment, and surgical planning in oculofacial surgery

AI applications in oculofacial plastic surgery, mainly for disease diagnosis, assessment/management, and surgical planning, have seen a tremendous increase over the past years.[75]

Eyelid diseases

Deep learning models with decision-making capacity are used in oculofacial plastic surgery to guide nonexpert physicians in diagnosing eyelid diseases. Blepharoptosis is the most common eyelid disease, with prevalence reaching up to 15% in adults based on region.[76,77] A convolutional neural network (CNN) using smartphones showed a sensitivity of 83%, specificity of 82.5%, and area under the curve (AUC) of 0.900 in diagnosing blepharoptosis.[78] With the goal of outperforming the original CNN, two other models were created by the same team, which showed greater performance in identifying blepharoptosis.[79,80]

In addition to common eyelid conditions, deep learning models are increasingly being applied to eyelid tumors. DenseNet121, a CNN, has classified lesions in pathological eyelid photographs as malignant or benign. The top three most common malignant eyelid lesions identified were basal cell carcinoma (BCC; 65.9%), squamous cell carcinoma (SCC; 13.4%), and sebaceous gland carcinoma (17.7%), whereas the top three benign lesions were squamous cell papilloma (9.0%), nevus (33.2%), and seborrheic keratosis (9.1%). Internal and external AUC values of 0.899 and 0.955 were reported in this study.[81] Diagnostic challenges exist for eyelid tumors; a recent study in South India found that up to 40% of SCC can be misdiagnosed.[82] Once optimized and properly validated, AI-assisted diagnostic tools for periocular diseases have the potential to provide global screening and support non-experts in clinical decision-making.

Eyelid assessment involves measuring palpebral fissure, MRD1/2, and levator function. Measurement variability, especially among trainees (residents, fellows), can reduce ocular examination reliability, a limitation that AI-based tools can help overcome. A recent machine learning (ML) algorithm using patient photographs who underwent upper eyelid blepharoplasty surgery with or without Müller's muscle conjunctival resection showed satisfactory repeatability for patient assessment.[83] More recently, a team sought to combine the technology of smartphones (i.e., iOS devices) with an AI-based algorithm to predict ocular parameters using photographs.[84] By comparing the values generated by the algorithm with the gold standard measurements, the researchers demonstrated an excellent agreement between the gold standard measurements and the values predicted with the MRD1 and MRD2 models, 0.90 and 0.84, respectively.[84]

Deep learning models provide interesting features for oculofacial plastic surgeons in terms of surgical planning and prediction of surgical outcomes. Surgical complexity is a crucial factor in surgical preparation. With the aim of providing surgical assistance, a team developed a decision tree model predicting the complexity of excisional reconstructive surgery for patients with BCC using a three-variable risk stratification system.[85] Surgical complexity was determined successfully with an AUC of 0.853.[85] Outcome prediction can also be useful for patients during decision-making counseling. A team established a deep learning-based postoperative appearance prediction system for patients undergoing blepharoplasty surgery: the obtained similarity scale was of 9.43 ± 0.79.[86] Similar approaches have been explored for ptosis repair, where precise measurements from 3D facial reconstruction were used to construct a decision model for ptosis surgery.[87] These predictive models may assist surgeons in planning surgical technique selection and setting realistic patient expectations.

Orbital diseases

TED is a growing field of application for AI-based tools. Using extraocular photographs, deep learning models have been trained to accurately detect TED signs (e.g., eyelid retraction, eyelid congestion, eyelid edema, conjunctival congestion, and ocular dyskinesia) with an area under the receiver operating curve of >0.90 for all signs, except for chemosis and corneal ulcers. Similar technologies have been developed by other research team,[88] helping nonexpert clinicians diagnose TED, which is often misdiagnosed as relapsing conjunctivitis.[89] By using the U-Net++ model as a backbone, a deep learning algorithm generated automated exophthalmos measurement based on CT images, achieving concordance correlation coefficient and intraclass correlation coefficient values of 0.9895 and 0.9698, respectively, with axial CT images.[90] Conventional clinical methods are limited by their poor reproducibility and subjectivity, challenges that deep learning models can overcome. AI-based tools can additionally monitor disease response to treatment.[91]

Text-to-image preoperative counseling

Publicly available text-to-image models have gained interest among oculofacial plastic surgeons for their ability to improve preoperative education, counseling, and discussion of expected results. Text-to-image models are generative models that produce synthetic images from textual inputs.[92] Studies using Open AI's DALL.E editor have shown its ability to produce accurate postoperative pictures for eyelid surgeries while using image and/or text as inputs,[93,94] with similar applications reported for lip-lift procedures.[95] Clinicians should exercise caution, however, as predicted outcomes may not always perfectly match real surgical results, potentially leading to patient disappointment.

Conclusion

Significant advances in imaging and surgical technologies have transformed oculofacial plastic surgery over the past decades. High-resolution endoscopy and exoscopy, 7T MRI, and stereotactic navigation have made procedures safer and more precise, while AI tools are increasingly helping with diagnosis, surgical planning, and outcome prediction. For instance, CNNs have been applied to blepharoptosis and eyelid tumor diagnosis, ML models have predicted surgical complexity and postoperative eyelid position, and deep learning has enabled automated orbital measurements and outcome simulations in blepharoplasty and ptosis repair. Despite this progress, challenges remain, including high costs, steep learning curves, and the need to validate new technologies in real-world practice.[96] In fact, a recent survey demonstrated that close to 70% of oculofacial plastic surgeons do not use intraoperative stereotactic navigation for their orbital decompression surgeries, most likely due to these limitations.[97]

Future developments will be driven by high-resolution and functional imaging, augmented and mixed reality, and AI applications, all of which have the potential to enhance preoperative assessment, intraoperative guidance, and postoperative outcomes. For oculoplastic surgeons, the key challenge is to integrate these technologies where they meaningfully improve care. Endoscopic and exoscopic systems can enhance visualization, stereotactic navigation, and high-resolution MRI provide guidance in complex orbital procedures, and advanced photographic and 3D analyses refine eyelid and periocular assessments. Emerging AI tools offer opportunities for earlier diagnosis, individualized planning, and outcome prediction, although their application in clinical practice remains at an early stage. Achieving this will require collaboration between clinicians and researchers, rigorous validation, careful attention to accessibility, and adherence to ethical standards regarding patient data and algorithm use. Successfully addressing these factors promises not only safer and more precise surgery but also a shift toward truly patient-centered, minimally invasive, and ethically responsible oculofacial care.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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Conflicts of interest

The authors declare that there are no conflicts of interest in this paper.

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