Table 1 Summary table for the artificial intelligence-based systems in the detection of anterior segment ocular diseases

Reference	Aim	Datasets	Algorithms	Performance	Conclusion
Conjunctiva and tear film					
Barral *et al.* 2017 (24) (Departamento de Computación, Universidade da Coruña)	Tear film lipid layer classification	Tear film lipid layer interference images/105	MLP, SVM and Fisher classifier	Best AUC: 0.95 MLP > SVM > Fisher	A methodology for evaluating tear film classification, i.e., an automatic test for dry eye diagnosis, has been presented, and its effectiveness has been demonstrated
Sánchez *et al.* 2016 (39) (Department of Computer Science, University of A Coruna)	Conjunctival hyperemia grading	Slit-lamp images/70	MLP	AUC: 0.841 Sensitivity: 91.0% Specificity: 75.0%	The results show that the automatic procedure behaves like an expert using only a limited region of interest within the conjunctiva
Koh *et al.* 2012 (40) (Bioinformatics Institute of Singapore)	Meibomian gland dysfunction detection	Meibography images/55	SVM	Sensitivity: 97.9% Specificity: 96.1%	The user-free computational method is fast, does not suffer from inter-observer variability, and can be useful in clinical studies where large number of images needs to be analyzed efficiently
Derakhshani *et al.* 2012 (41) (Department of Computer Science Electrical Engineering, University of Missouri at Kansas City)	Conjunctival hyperemia grading	Macro RGB eye images/271	ANN	Correlation coefficient: 0.89	The neural network-based method is more accurate but at the same time computationally more expensive during training (but not post training)
Yedidya *et al.* 2009 (42) (Australian National University, and National ICT Australia)	Break-up time calculation	Frontal eye videos after fluorescein instillation/22	MRF	Average difference between a clinician's break-up time and MRF: 2.34 s	Demonstrates how an asymmetric graph-cuts approach, can be used to segment dryness
Grus *et al.* 2005 (43) (Department of Ophthalmology, University of Mainz)	Dry eye detection	Tear film proteins/159 subjects	ANN	AUC: 0.93 Sensitivity: 90% Specificity: 90%	The SELDI-TOF-MS technology seems to be ideally suitable for the mass screening of peptides and proteins in tears. This highly sensitive approach dramatically reduces the analysis time and provides protein profiles with great mass accuracy
Cornea					
Kumar *et al.* 2018 (34) (Department of Electronics and Communication Engineering, Pondicherry Engineering College)	Corneal arcus and cataract detection	Visible wavelength eye images/228	SVM	AUC: 96.96% Sensitivity: 97% Specificity: 99%	The performance measures clearly indicate that the experimental results are clinically significant and the proposed method can be used to assist the ophthalmologists
Lopes *et al.* 2018 (31) (Department of Ophthalmology of Federal University of São Paulo, São Paulo, Brazil)	Corneal ectasia detection	Pentacam HR parameters /3693 patients	A combination of RDA, SVM, NB, ANN, and RF	AUC: 0.992 Sensitivity: 94.2% Specificity: 98.8%	The Pentacam Random Forest Index enhances ectasia diagnosis
Ruiz *et al.* 2016 (32) (Department of Ophthalmology, Antwerp University Hospital, Edegem, Belgium)	Forme fruste keratoconus detection, keratoconus detection, 5-group classification of corneal conditions	Pentacam HR parameters /860 eyes	SVM	Forme Fruste keratoconus detection AUC: 93.1% Sensitivity: 79.1% Specificity: 97.9% Keratoconus detection AUC: 98.9% Sensitivity: 99.1% Specificity: 98.5%	The present study obtained comparable or better results than the single parameter methods and indices reported in the literature
Kovacs *et al.* 2016 (30) (Department of Ophthalmology, Semmelweis University)	Preclinical keratoconus detection	Pentacam HR parameters/75 patients	ANN	AUC: 0.96	Automatic classifiers trained on bilateral data were better than single parameters in discriminating fellow eyes of patients with unilateral keratoconus with preclinical signs of keratoconus from normal eyes
Smadja *et al.* 2013 (33) (Anterior Segment and Refractive Surgery Unit, University Center Hospital of Bordeaux)	Forme fruste keratoconus detection, keratoconus detection	GALILEI system parameters/ 372 eyes	The classification and regression tree	Forme fruste keratoconus detection Sensitivity: 93.6% Specificity: 97.2% Keratoconus detection Sensitivity: 100% Specificity: 99.5%	The machine learning classifier showed very good performance for discriminating between normal corneas and forme fruste keratoconus and provided a tool that is closer to an automated medical reasoning
Arbelaez *et al.* 2012 (29) (Muscat Eye Laser Center, Muscat, Oman)	Keratoconus detection, subclinical keratoconus detection	Sirius software parameters /3502 eyes	SVM	Keratoconus detection AUC: 96.9% Sensitivity: 92.8% Specificity: 98.2% Subclinical keratoconus detection AUC: 93.3% Sensitivity: 75.2% Specificity: 94.9%	The classification algorithm showed high accuracy, precision, sensitivity, and specificity in discriminating among abnormal eyes, eyes with keratoconus or subclinical keratoconus, and normal eyes
Souza *et al.* 2010 (44) (Faculdade de Medicina da Universidade de São Paulo)	Keratoconus detection	Orbscan II parameters/318 eyes	SVM, MLP, and RBFNN	AUC: 0.98–0.99 Sensitivity: 98–100% Specificity: 98%	SVM, MLP and RBFNN were effective in detecting keratoconus. There were no differences between the classifiers' performance
Zhang *et al.* 2018 (17) (School of Computer Science and Technology, Xidian University)	Identification, localization and treatment suggestion of keratitis and other diseases	Slit-lamp images/1513	CNN	Accuracy: 93% (identification)	This system can identify the disease, distinguish different anatomical parts and foci, discern the diagnostic information relevant to the diagnosis of diseases, and provide treatment suggestions
Wu *et al.* 2017 (45) (Shandong University)	Hyphae detection	Confocal microscopy images	SVM	Accuracy: 99.74%	The experimental results demonstrate the effectiveness of the proposed framework
Glaucoma (anterior segment invloved)					
Fu *et al.* 2019 (18) (Cixi Institute of Biomedical Engineering, Chinese Academy of Sciences)	Angle-closure detection	AS-OCT images/4135	CNN	AUC: 0.96 Sensitivity: 90% Specificity: 92%	The results demonstrate the potential of the deep learning system for angle-closure detection in AS-OCT images
Wang *et al.* 2019 (46) (Schepens Eye Research Institute, Harvard Medical School)	Visual field progression detection	Visual field data/12,217 eyes	Archetype Method	Agreement (kappa): 0.51 Accuracy: 0.77	The archetype method can inform clinicians of visual field progression patterns
Aloudat *et al.* 2018 (35) (Department of Computer Science and Engineering, University of Bridgeport)	High intraocular pressure detection	Frontal eye images/400	Decision tree and SVM	Accuracy: 95.5% (SVM); 80.25% (Decision tree)	A novel automated non-contact and non-invasive framework has been proposed for analyzing frontal eye images to help in the early assessment of intraocular pressure risk
Martin *et al.* 2018 (47) (Department of Ophthalmology, Cambridge University)	Primary open-angle glaucoma detection	Contact lens sensor parameters /435 subjects	RF	AUC: 0.611	Contact lens sensor recordings contain information complementary to intraocular pressure that enable discrimination between healthy eyes and primary open-angle glaucoma
Niwas *et al.* 2016 (21) (School of Computer Engineering, Nanyang Technological University)	Angle closure glaucoma mechanism classification	AS-OCT images/74	NB	Accuracy: 89.2%	Proposes a fully automated way for the classification of different angle-closure glaucoma mechanisms, which is without intervention of doctors and less subjective when compared to existing methods
Xu *et al.* 2013 (48) (the Institute for Infocomm Research, Agency for Science, Technology and Research, Singapore)	Angle-closure detection	OCT images/2048	SVM	AUC: 0.921 Accuracy: 84.0% Specificity: 85%	For glaucoma type identification, an image processing and machine learning based framework was proposed to localize and classify anterior chamber angle accurately and efficiently, based on visual features only. The framework outperforms existing methods based on clinical features
Nongpiur *et al.* 2013 (23) (Singapore Eye Research Institute and Singapore National Eye Center, Singapore)	Angle closure detection	6 AS-OCT parameters/1368 subjects	Stepwise logistic regression, RF, Mars algorithm, SVM and NB	Best AUC: 0.956 from stepwise logistic regression	A classification algorithm based on stepwise logistic regression that used a combination of 6 parameters obtained from a single horizontal AS-OCT scan identified subjects with gonioscopic angle closure >95% of the time
Cataract					
Xu *et al.* 2019 (16) (School of Software Engineering, Beijing University of Technology)	Cataract grading	Retinal fundus images/8030	SVM and DCNNs	Best accuracy: 86.24% from Global-local (Majority Voting)	Global-local feature representation model to improve the recognition performance of automatic cataract grading
Wu *et al.* 2019 (49) (State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University)	Capture mode recognition, cataract diagnosis, detection of referable cataracts	Slit-lamp images/37638	CNN (ResNet)	Capture mode recognition AUC: 99.28–99.71% Cataract diagnosis AUCs >99% in all capture modes Detection of referable cataracts AUCs >91% in all tests	The universal AI platform and multilevel collaborative pattern showed robust diagnostic performance and effective service for cataracts. The context of our AI-based medical referral pattern will be extended to other common disease conditions and resource-intensive situations
Lin *et al.* 2019 (12) (State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University)	Pediatric cataract detection and treatment suggestion	Slit-lamp images/175 subjects	DCNN	Accuracy: 87.4% (detection), 70.8% (treatment suggestion)	CC-Cruiser exhibited less accurate performance comparing to senior consultants in diagnosing childhood cataracts and making treatment decisions. However, the medical service provided by CC-Cruiser was less time-consuming and achieved a high level of patient satisfaction
Jiang *et al.* 2018 (50) (School of Computer Science and Technology, Xidian University)	Posterior capsule opacification progress prediction	Retro-illumination images/6090	Combinations of CNN and LSTM (or RNN)	Best AUC: 0.9718	Provides a promising strategy for the progression of ophthalmic disease, and has the potential to be applied in other medical fields
Long *et al.* 2017 (14) (State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Centre)	Congenital cataract detection and treatment suggestion	Slit-lamp images/886	DCNN	Accuracy: 98.87% (detection), 97.56% (treatment suggestion)	The AI agent using DL have the ability to accurately diagnose and provide treatment decisions for congenital cataracts. And the AI agent and individual ophthalmologists perform equally well. A cloud-based platform integrated with the AI agent for multihospital collaboration was built to improve disease management
Long *et al.* 2017 (51) (State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University)	Pediatric cataract risk prediction	8 input variables/160 subjects	SEM	Goodness-of-fit P=0.1113	Proposes a generalized evidence-based pattern for rare and complex disease data mining, provides new insights and clinical implications on pediatric cataract, and promotes rare-disease research and prevention to benefit patients
Gao *et al.* 2015 (11) (Institute for Infocomm Research, Agency for Science, Technology and Research, Singapore)	Nuclear cataracts grading	Slit-lamp images/5378	CRNN	Exact agreement ratio (R_0): 70.7% Decimal grading error ≤0.5 ($R_{\leq 0.5}$): 88.4% Decimal grading error ≤1.0 ($R_{\leq 1.0}$): 99.0%	The proposed method is useful for assisting and improving clinical management of the disease in the context of large-population screening and has the potential to be applied to other eye diseases
Mohammadi *et al.* 2012 (52) (Eye Research Center, Farabi Eye Hospital)	Posterior capsule opacification prediction	10 input variables/352 eyes	ANN	Best AUC: 89%	A prototype artificial neural network was developed that predicted posterior capsule status (requiring capsulotomy) with reasonable accuracy
Acharya *et al.* 2010 (10) (Department of Electronics and Computer Engineering, Ngee Ann Polytechnic, Singapore)	Cataract and post-cataract surgery classification	Slit-lamp images/140	ANN	ACU:93.3% Sensitivity: 98% Specificity:100%	The results are clinically significant. This system can also be used to test the efficacy of the cataract operation by testing the post-cataract surgery optical images
Findl *et al.* 2004 (53) (Departments of Ophthalmology, Medical University of Vienna)	Postoperative effective lens position prediction	Preoperative biometry measurements/77 eyes	MLP	Corelation coefficient: 0.68	The prediction of postoperative anterior chamber depth with the MLP was not significantly better than the prediction using linear regression

AUC, area under the curve; AS-OCT, anterior segment optical coherence tomography; OCT, optical coherence tomography; MLP, multi-layer perception; SVM, support vector machine; ANN, artificial neural network; MRF, Markov random fields; RDA, range doppler algorithm; NB, naïve Bayes; RF, random forest; RBFNN, radial basis function neural network; CNN, convolutional neural network; DCNN, deep convolutional neural network; LSTM, Long short-term memory; RNN, recurrent neural network; SEM, Structural equation modeling; CRNN, convolutional recurrent neural network.