

PERCEPTION OF OPTOMETRISTS IN PAKISTAN REGARDING THE INTEGRATION OF AI IN OPTOMETRY

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Abstract

OBJECTIVE: To assess the perception of optometrists in Pakistan toward the integration of artificial intelligence (AI) into eye care.

METHOD: A cross-sectional survey was conducted from June to November 2024 at the College of Ophthalmology and Allied Vision Sciences, Mayo Hospital, Lahore. Ethical approval was obtained from the institutional review board before the study. A total of 312 registered optometrists across Pakistan participated through convenience sampling. Data were collected using a structured questionnaire distributed online, covering demographics, familiarity with AI, concerns, and willingness to integrate AI into clinical practice. Statistical analysis was performed using SPSS version 25. Descriptive statistics and Chi-square tests were used, with $p < 0.05$ considered statistically significant.

RESULTS: A total of 312 optometrists participated in the survey. Most respondents (78.8%) agreed that AI would enhance optometric practice, while 67.0% expressed concerns about its diagnostic reliability. Higher willingness to adopt AI was observed after the COVID-19 pandemic (64%) compared with before the pandemic (45%) ($p = 0.02$). Female optometrists ($p = 0.01$) and recent graduates (2020–2024) ($p = 0.01$) were more likely to report concerns regarding AI's diagnostic accuracy and its potential to replace doctors. Additionally, 76.7% of respondents supported integrating AI into optometry education. Positive perceptions of AI were associated with private

practice and residency experience, including agreement that AI could improve optometric practice (92.2%, $p < 0.001$). Qualitative analysis of free-text responses identified four main themes: concerns about diagnostic accuracy, professional concerns regarding replacement of doctors, implementation barriers such as cost and training, and perceived benefits including improved efficiency and access to eye care.

CONCLUSION: Pakistani optometrists demonstrated a generally positive attitude toward the integration of AI into eye care. However, concerns regarding the diagnostic reliability of AI systems remained common, highlighting the need for further validation, professional training, and appropriate regulatory oversight before widespread implementation.

INTRODUCTION:

Artificial intelligence is a branch of computer science specializing in designing systems to complete tasks that especially require human intelligence, such as speech recognition, visual perception, and decision-making.¹ Capabilities that were also considered impossible ten years ago are common applications of AI now; features such as speech recognition and image processing were considered impossible capabilities until recently. Machine learning is another of the sub-technologies that make up AI and allows these systems to perform specific tasks through the recognition of patterns without explicit programming.² AI can be seen in every house today since it is one of the biggest tools embedded into daily life, utilizing personal assistants such as Siri, Alexa, autonomous transportation, and video games.

AI's reach in healthcare is broad, improving areas that require accuracy and quick data interpretation. It's already used in radiology, pathology, and dermatology, where algorithms assist doctors by swiftly analyzing large datasets and images.³ In optometry, AI shows tremendous promise in improving the detection and management of eye diseases like diabetic retinopathy, glaucoma, and age-related macular degeneration (AMD).⁴ Offline AI systems now run on smartphones, broadening access to these technologies. Beyond image analysis, AI applications in ophthalmology extend to intraocular lens power calculations, myopia

prediction, keratoconus detection, and advanced electronic medical records, indicating AI's transformative potential in optometry and beyond.⁵

Big technology companies are also developing AI tools for ophthalmology. Google's DeepMind has shown its ability to classify 50 different eye conditions directly from Optical Coherence Tomography scans for triage and further referral in partnership with Moorfields Eye Hospital.²⁰ IBM's AI can predict visual field data from OCT scans, while Microsoft's Intelligent Network for Eyecare (MINE) is working with a group of global organizations to scale eye care delivery and address avoidable blindness. There are many commercial AI products, such as IDx-DR, Medios AI, Pegasus-V, and LIFE, Leah, which have recently come into the markets and have been assessed periodically by researchers for clinical utility.

Artificial intelligence (AI) has the potential to transform optometry by increasing the effectiveness of diagnostic procedures, decreasing errors at various disease stages, and facilitating more individualized treatment plans. Additionally, AI-powered solutions can help close access gaps to eye care services, particularly in underprivileged areas with a shortage of optometrists. This would also guide educational initiatives, continuing professional development programs, and policies to help drive the penetration of AI within optometric practice.

To find out the potential role and acceptance of AI in optometric practice, it is first necessary to

understand provider perceptions towards AI. Previous studies on health care provider and trainee perceptions of AI have reported a willingness to incorporate AI into clinical practice.⁷ The research aims to determine what motivates optometrists to adopt AI and how best to integrate it by looking at these elements through surveys and qualitative data collection.

Materials And Methods:

This cross-sectional survey was coordinated at the College of Ophthalmology and Allied Vision Sciences, Mayo Hospital, Lahore, Pakistan, between June and November 2024. Participants were registered optometrists practicing across Pakistan and were recruited nationally through professional networks and social media platforms, including WhatsApp and Facebook, as well as through printed questionnaires distributed at professional settings. A convenience sampling method was used for participant recruitment through both online and printed questionnaire distribution. Although this approach facilitated nationwide participation, it may have introduced selection bias and is acknowledged as a limitation of the study.

Ethical approval was obtained from the Institutional Review Board (IRB) of the College of Ophthalmology and Allied Vision Sciences (COAVS), King Edward Medical University, Lahore, Pakistan (Approval No. COAVS/114A/24), approved on 24 April 2024. The study was conducted in accordance with the principles of the Declaration of Helsinki (2013 revision). Written informed consent was obtained from all participants before enrollment. Participation was voluntary, responses were anonymized, and all data were treated confidentially throughout the study.

The sample size was calculated using a single-population proportion formula $n = \frac{z_{1-\alpha/2}^2 P(1-P)N}{d^2(N-1) + z_{1-\alpha/2}^2 P(1-P)}$ with a 95% confidence level, an anticipated population proportion of 0.5 (the conservative default used in the absence of a prior local estimate for this population), and a

margin of error of 5%, resulting in a target sample of approximately 385 participants. A total of 312 completed responses were obtained and included in the final analysis.

The questionnaire was developed by the research team following a review of previously published surveys assessing healthcare professionals' perceptions of artificial intelligence. The questionnaire comprised three sections: demographic characteristics, familiarity with and perceptions of artificial intelligence using a five-point Likert scale (Strongly Disagree to Strongly Agree), and an optional free-text section to capture additional opinions and perceived barriers. Content relevance and clarity were reviewed by two senior optometry faculty members before distribution. Formal psychometric validation, including pilot testing, construct validation, and prospective assessment of internal consistency using Cronbach's alpha, was not performed prior to survey deployment and is acknowledged as a limitation of the study. As a post-hoc check, internal consistency was nonetheless assessed retrospectively on the collected data: the four items addressing acceptance of AI integration (curriculum inclusion, perceived improvement to practice, and willingness to adopt before and after the COVID-19 pandemic) demonstrated acceptable internal consistency (Cronbach's $\alpha = 0.74$), whereas the three items addressing distinct sources of concern (diagnostic accuracy, professional displacement, and the doctor-patient relationship) did not cohere as a single scale (Cronbach's $\alpha = 0.47$), consistent with these items capturing conceptually distinct concerns rather than a unidimensional construct and supporting our decision to report them individually rather than as a composite score. This post-hoc reliability estimate does not substitute for prospective validation and is reported only to contextualize, rather than resolve, the absence of formal instrument validation.

Only registered optometrists who provided informed consent were eligible to participate. Optometry students, incomplete responses, and individuals unable to complete the questionnaire

in English were excluded. In this study, residency refers to structured postgraduate clinical training in optometry undertaken at an accredited institution in Pakistan following completion of an undergraduate optometry degree.

Statistical analysis was performed using SPSS version 25 (IBM Corp., Armonk, NY, USA). Categorical variables were summarized using frequencies and percentages, while continuous variables were expressed as means $\pm$ standard deviations where appropriate. Associations between categorical variables were assessed using the Chi-square test, and results were reported with corresponding p-values. Cramér's V was calculated for selected statistically significant associations to estimate effect size. Statistical significance was set at $p < 0.05$.

Free-text responses were analyzed using reflexive thematic analysis following the six-phase framework described by Braun and Clarke. Responses were independently coded by two authors (D.Y. and A.M.), who generated initial codes, compared interpretations, and resolved discrepancies through discussion until consensus was achieved. Related codes were grouped into broader themes, which were reviewed, defined, and supported with representative participant quotations. The illustrative coding framework

underlying the four final themes is presented in Table 2a. Formal inter-coder agreement statistics, such as Cohen's kappa, were not calculated and are acknowledged as a methodological limitation.

Results:

A total of 312 optometrists participated in the survey. Most respondents, 78.8%, agreed that AI would enhance optometric practice, although 67% expressed concerns about its diagnostic reliability. Post-COVID-19, willingness to adopt AI in practice increased significantly from 45% to 64% ($p=0.02$). Female optometrists ($p=0.01$) and recent graduates (2020–2024) ($p=0.01$) were more likely to have concerns about AI's accuracy and its potential to replace doctors. Additionally, 76.7% of respondents supported integrating AI into optometry education. Optometrists in private practice and those with residency experience showed more positive perceptions of AI, particularly regarding its potential to improve practice. Qualitative analysis of free-text responses identified four themes: diagnostic accuracy concerns, professional concerns about replacement of doctors, implementation barriers, and perceived benefits such as efficiency and improved access to care. The demographics are described in table 01.

Table 01: Demographics

Variables	Subgroups	No. of participants (%)
Gender	Female	201(64.4)
	Male	111(35.6)
Year of graduation	2008-2011	3(1.0)
	2012-2015	14(4.5)
	2016-2019	63(20.2)
	2020-2024	232(74.4)
Mode of Practice	Community Health Centre	21(6.7)
	Govt. Employed	22(7.1)
	Optical Company Employed	79(25.3)
	Private optometry practice	190(60.9)
Completion of Residency	Yes	236(75.6)

	No	76(24.4)
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The distribution in Fig 1 indicates generally positive attitudes toward AI among optometrists, with a majority agreeing that AI should be incorporated into the curriculum and will improve optometry practice.

Willingness to adopt AI increased after the COVID-19 pandemic, while moderate concerns persist regarding diagnostic reliability and the doctor-patient relationship. Distribution of optometrists' attitudes toward AI integration,

showing percentage responses across eight Likert-scale items (familiarity with AI, concerns about diagnostic reliability, concerns about AI replacing doctors, concerns about harm to doctor-patient relationship, inclusion in optometry curriculum, expected improvement of practice, and willingness to adopt AI before and after the COVID-19 pandemic). Responses are categorized as Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree (n = 312)

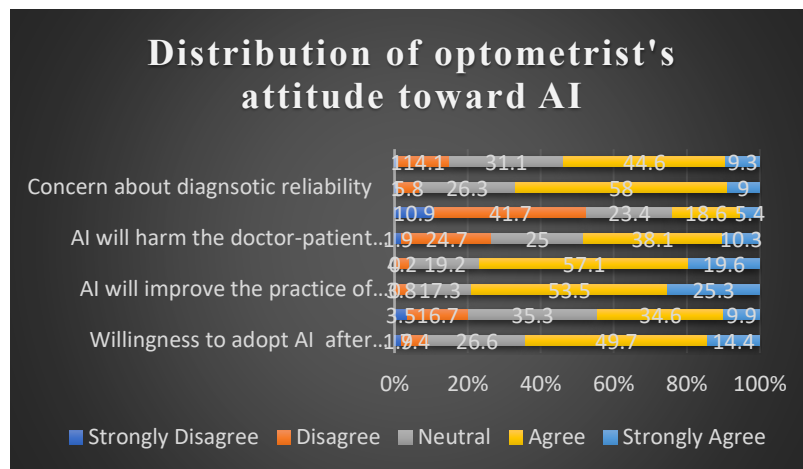


Fig. 1 Distribution of optometrists' attitudes toward AI across eight survey items.

Qualitative Free-Text Responses:

Of 312 respondents, 187 (59.9%) provided written comments. Four main themes emerged from thematic analysis: (1) technical concerns about diagnostic accuracy, (2) professional concerns about job displacement or replacement of doctors, (3) implementation barriers including cost, infrastructure, and training, and (4) positive perceptions regarding efficiency and improved access to eye care.

Technical concerns about diagnostic accuracy were the most frequently reported theme (n=89, 47.6%). Respondents emphasized that AI systems require further clinical validation before routine use. A representative response was: "AI needs more validation before clinical adoption."

Professional concerns about job displacement were reported by 67 respondents (35.8%). Participants stated that optometrists should not become overdependent on AI and should continue to maintain clinical and diagnostic skills. A representative response was: "Future optometrists must retain diagnostic skills."

Implementation barriers were reported by 54 respondents (28.9%). These included financial cost, lack of infrastructure, limited access to AI-based systems, and the need for professional training. A representative response was: "Implementation requires infrastructure investment."

Positive perceptions were reported by 42 respondents (22.5%). Respondents highlighted that AI could improve efficiency, screening,

referral systems, and access to eye care in underserved or rural areas. A representative response was: “Could improve rural eye care access.”

Since some comments addressed more than one issue, the total number of coded responses exceeded the number of respondents who provided comments as described in table 02.

Table 02: Thematic analysis of free-text responses regarding AI integration in optometry

Theme	Main issue identified	n (%) among free-text respondents	Representative quotation
Technical concerns about diagnostic accuracy	Need for validation, reliability, risk of diagnostic errors, dependence on image/data quality	89 (47.6%)	“AI needs more validation before clinical adoption.”
Professional concerns about replacement of doctors	Fear of job displacement, reduced clinical skills, overdependence on AI	67 (35.8%)	“Future optometrists must retain diagnostic skills.”
Implementation barriers	Cost, infrastructure, lack of training, limited availability of technology	54 (28.9%)	“Implementation requires infrastructure investment.”
Positive aspects regarding efficiency and access	Faster screening, improved workflow, tele-optometry, rural eye care access	42 (22.5%)	“Could improve rural eye care access.”

Percentages were calculated using the number of respondents who provided free-text responses as the denominator (n=187). Responses could be

coded under more than one theme; therefore, percentages do not total 100%.

Table 2a: Illustrative Coding Framework Underlying the Four Qualitative Themes

Code	Illustrative excerpt	Parent theme
Need for further clinical validation	“AI needs more validation before clinical adoption.”	Technical concerns about diagnostic accuracy
Risk of diagnostic error	Concern that AI misclassification could affect patient outcomes	Technical concerns about diagnostic accuracy
Dependence on image/data quality	Concern that AI performance depends on image and data quality	Technical concerns about diagnostic accuracy
Fear of job displacement	“Future optometrists must retain diagnostic skills.”	Professional concerns about replacement of doctors

Code	Illustrative excerpt	Parent theme
Reduced reliance on clinical/diagnostic skills	Concern that trainees may over-rely on AI output	Professional concerns about replacement of doctors
Overdependence on AI	Concern about diminished clinical judgement over time	Professional concerns about replacement of doctors
Cost and financial constraints	"Implementation requires infrastructure investment."	Implementation barriers
Lack of infrastructure	Concern about limited technical infrastructure in clinics	Implementation barriers
Need for training	Concern about insufficient AI-related training for staff	Implementation barriers
Improved efficiency and workflow	"Could improve rural eye care access."	Positive perceptions of efficiency and access
Improved access in underserved/rural areas	Comments on AI expanding reach of eye care services	Positive perceptions of efficiency and access
Tele-optometry and referral potential	Comments on AI supporting screening and referral pathways	Positive perceptions of efficiency and access

Codes were generated inductively from the free-text responses by two independent coders (D.Y. and A.M.), then grouped into the broader categories shown above; discrepancies in code assignment were resolved through discussion until consensus was reached on theme boundaries.

Table 03: Familiarity with AI & diagnostic accuracy concern

Familiarity with AI in eye care					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P- value
Mode of Practice	Community health	9	11	1	0.01
	Govt.	18	3	1	
	Optical company	44	20	15	
	Private	97	63	30	
Concern about diagnostic accuracy					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P-value
Graduation Year	2008-11	0	2	1	0.01
	2012-15	5	7	2	
	2016-19	44	14	5	
	2020-24	160	59	13	
Gender	Male	75	24	12	0.01
	Female	134	58	9	
Calculated by Chi-square test.					

There was a statistically significant association between mode of practice and familiarity with AI in eye care (Chi-square test, $p = 0.01$), with private practitioners and optical company employees showing higher levels of agreement. Table 03 shows the familiarity of optometrists regarding diagnostic accuracy concern.

Concern about diagnostic accuracy was also significantly associated with both year of graduation and gender ($p = 0.01$), with more recent graduates and female optometrists reporting higher levels of concern.

Table 04: Concerns About AI in Eye Care.

Concern about AI replacing doctors					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P-value
Graduation Year	2008-11	0	0	3	0.01
	2012-15	1	2	11	
	2016-19	7	16	40	
	2020-24	67	55	110	
Residency	Yes	52	48	136	0.01
	No	23	25	28	
Gender	Male	19	22	70	<0.001
	Female	56	51	94	
Mode of Practice	Community health	12	1	8	<0.001
	Govt. Employee	7	2	13	
	Optical company	21	20	38	
	Private	35	50	105	
Concern about AI harming doctor-patient relationship					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P-value
Graduation Year	2008-11	0	1	2	<0.01
	2012-15	7	2	5	
	2016-19	31	12	20	
	2020-24	113	63	56	
Residency	Yes	116	53	67	0.15
	No	35	25	16	
Gender	Male	58	28	25	0.45
	Female	93	50	58	

Mode of Practice	Community health	12	6	3	0.24
	Govt. Employee	9	4	9	
	Optical company	32	26	21	
	Private	98	42	50	
Calculated by Chi-square test.					

Concern about AI replacing doctors showed significant associations with graduation year, residency status, gender, and mode of practice (Chi-square test; $p \leq 0.01$), with recent graduates and female participants demonstrating comparatively higher levels of concern, as shown in table 04.

Similarly, concern regarding AI harming the doctor-patient relationship was significantly associated with year of graduation ($p < 0.01$), with more recent graduates expressing greater apprehension.

Table 05: Perceptions About AI Integration in Optometry Education and Practice.

AI should be part of optometry curriculum					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P-value
Residency	Yes	189	40	7	<0.01
	No	50	20	6	
	Govt. Employee	17	5	0	
	Optical company	60	15	4	
	Private	149	33	8	
AI will improve the practice of optometry					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P-value
Residency	Yes	195	35	6	<0.01
	No	51	19	6	
Gender	Male	96	13	2	<0.01
	Female	150	41	10	
Calculated by Chi-square test.					

A significant association was observed between residency status and positive perceptions toward AI, including its potential benefits and role in optometry practice (Chi-square test; $p < 0.01$).

Additionally, gender showed a significant association with the belief that AI will improve optometry practice, with male participants demonstrating comparatively stronger agreement ($p < 0.01$). As shown in table 05.

Table 06. Binary Logistic Regression Predicting Acceptance of AI in Optometric Practice

Predictor	aOR	95% CI	p-value
Age	1.01	0.82–1.23	0.943

Predictor	aOR	95% CI	p-value
Gender	2.03	1.02–4.04	0.045
Residency completed	2.20	1.13–4.27	0.020
Familiarity with AI	3.02	1.65–5.54	<0.001

Binary logistic regression was performed to identify independent predictors of positive perceptions regarding AI in optometric practice. Greater familiarity with AI was independently associated with increased odds of agreeing that AI would improve optometric practice (aOR = 3.02, 95% CI: 1.65–5.54, $p < 0.001$). Completion of residency was also independently associated with

positive perceptions (aOR = 2.20, 95% CI: 1.13–4.27, $p = 0.020$). Female gender was associated with higher odds of positive perceptions compared with males (aOR = 2.03, 95% CI: 1.02–4.04, $p = 0.045$). Age was not significantly associated with AI acceptance (aOR = 1.01, 95% CI: 0.82–1.23, $p = 0.943$).

Table 07. Chi-square Associations with Effect Sizes

Association	$\chi^2(df)$	p-value	Cramér's V	Effect size
Mode of practice × Familiarity with AI	24.34 (12)	0.018	0.16	Small
Graduation year × Diagnostic accuracy concern	24.42 (12)	0.018	0.16	Small
Gender × Diagnostic accuracy concern	12.91 (4)	0.012	0.20	Small
Graduation year × AI replacing doctors	25.90 (12)	0.011	0.17	Small
Residency × AI replacing doctors	13.15 (4)	0.011	0.21	Small-moderate
Gender × AI replacing doctors	18.02 (4)	0.001	0.24	Small-moderate
Mode of practice × AI replacing doctors	37.06 (12)	<0.001	0.20	Small
Graduation year × Doctor-patient relationship	36.65 (12)	<0.001	0.20	Small
Residency × AI in curriculum	11.47 (3)	0.009	0.19	Small
Residency × AI improves practice	13.59 (3)	0.004	0.21	Small-moderate
Gender × AI improves practice	24.99 (3)	<0.001	0.28	Small-moderate
Graduation year × AI acceptance before COVID	24.51 (12)	0.017	0.16	Small
Residency × AI acceptance before COVID	12.01 (4)	0.017	0.20	Small
Graduation year × AI acceptance after COVID	23.28 (12)	0.025	0.16	Small
Residency × AI acceptance after COVID	10.66 (4)	0.031	0.18	Small

There was a statistically significant association between mode of practice and familiarity with AI in eye care ($\chi^2(12) = 24.34$, $p = 0.018$, Cramér's $V = 0.16$), indicating a small effect size.

Concern regarding the diagnostic accuracy of AI was significantly associated with year of graduation ($\chi^2(12) = 24.42$, $p = 0.018$, Cramér's $V = 0.16$) and gender ($\chi^2(4) = 12.91$, $p = 0.012$, Cramér's $V =$

0.20), with recent graduates and female optometrists reporting greater concern.

Concern that AI may replace doctors was significantly associated with year of graduation ($\chi^2(12) = 25.90$, $p = 0.011$, Cramér's $V = 0.17$), residency completion ($\chi^2(4) = 13.15$, $p = 0.011$, Cramér's $V = 0.21$), gender ($\chi^2(4) = 18.02$, $p = 0.001$, Cramér's $V = 0.24$), and mode of practice ($\chi^2(12) = 37.06$, $p < 0.001$, Cramér's $V = 0.20$).

Concern that AI may harm the doctor-patient relationship was significantly associated with year of graduation ($\chi^2(12) = 36.65$, $p < 0.001$, Cramér's $V = 0.20$).

Support for incorporating AI into the optometry curriculum was significantly associated with residency completion ($\chi^2(3) = 11.47$, $p = 0.009$, Cramér's $V = 0.19$).

The belief that AI would improve optometric practice was significantly associated with residency completion ($\chi^2(3) = 13.59$, $p = 0.004$, Cramér's $V = 0.21$) and gender ($\chi^2(3) = 24.99$, $p < 0.001$, Cramér's $V = 0.28$).

Willingness to adopt AI before the COVID-19 pandemic was significantly associated with year of graduation ($\chi^2(12) = 24.51$, $p = 0.017$, Cramér's $V = 0.16$) and residency completion ($\chi^2(4) = 12.01$, $p = 0.017$, Cramér's $V = 0.20$).

Similarly, willingness to adopt AI after the COVID-19 pandemic remained significantly associated with year of graduation ($\chi^2(12) = 23.28$, $p = 0.025$, Cramér's $V = 0.16$) and residency completion ($\chi^2(4) = 10.66$, $p = 0.031$, Cramér's $V = 0.18$).

Table 08: Willingness to adopt AI before and after pandemic.

Willingness to adopt AI before COVID					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P-value
Graduation Year	2008-11	2	0	1	0.01
	2012-15	7	5	2	
	2016-19	29	26	8	
	2020-24	101	79	52	
Residency	Yes	98	92	46	0.01
	No	41	18	17	
Willingness to adopt AI post-COVID					
Variable	Subgroups	Agree/Strongly agree	Neutral	Disagree/Strongly disagree	P-value
Graduation Year	2008-11	2	1	0	0.02
	2012-15	8	6	0	
	2016-19	46	15	2	
	2020-24	144	61	27	
1. Residency	Yes	155	61	20	0.03
	No	45	22	9	
Calculated by Chi-square test.					

Table 08 shows, Willingness to adopt AI before COVID-19 showed a significant association with both graduation year and residency status (Chi-

square test; $p = 0.01$), with more recent graduates demonstrating greater acceptance.

Post-COVID willingness to adopt AI was also significantly associated with graduation year and

residency completion ($p \leq 0.03$), indicating increased acceptance of AI following the pandemic.

Discussion:

The main findings of the study indicate that a majority of optometrists believe AI will advance optometry, though 67% (58% agree + 9% strongly agree) expressed concerns about its diagnostic accuracy. 76.7% of respondents supported teaching AI in optometry schools or residency programs. Following the onset of COVID-19, respondents became more receptive to incorporating AI into practice. The representation of optometrists with different experience levels was notable, with more than 60% being female and a recent cohort of graduates (2020–2024), which might influence openness to technology, as younger professionals tend to adapt better to emerging technologies. A significant portion (75.6%) had completed their residency, reflecting a level of clinical experience that enriches insights into adopting AI tools. The demographic composition of the sample, with 74.4% being recent graduates (2020–2024) and 64.4% female, may have influenced overall perceptions of AI. Younger graduates tend to be more digitally literate and may demonstrate greater openness to AI integration, potentially leading to an overestimation of acceptance among the broader optometrist population in Pakistan. Findings should therefore be interpreted with consideration of this demographic skew.

More than half of respondents had reservations about the precision of an AI diagnosis (67%), with significant differences observed based on gender ($p=0.01$) and graduation year ($p=0.01$). This concern may partially account for why 53.9% reported familiarity with AI; 15% disagreed. Previous studies have shown that AI algorithms can diagnose macular degeneration using retinal imaging with 80% to 90% accuracy, similar to that of skilled ophthalmologists.¹⁰ Another study evaluating AI in OCT in referral decision found an algorithm surpassed eight retina specialists and optometrists with the minimum error rate of only

3.5% and 75% accurate identification of all referrals.¹¹ Diagnostic accuracy in AI systems is largely dependent on the quality of input,¹² whereas many AI tools are being researched into their potential application in diagnosing, monitoring, and treating ocular conditions, most remain only experimental at present, and many will require validation before they become common in clinical use.

The participants involved in this study believe that AI will benefit optometric practice, as evidenced by a 78.8% approval rate among them, with significantly higher optimism observed among private practitioners ($p=0.01$) and residency-trained individuals ($p<0.01$). In a previous study, 70% of ophthalmologists concurred that AI would make a positive contribution to their practice.¹³ Also, in a survey conducted by professional Pottosantos among medical students 73% believed that AI will be an important factor in the practice of medicine.¹⁴ In this research, a quarter of optometrists reported concern over AI completely taking over the doctor's role, with females expressing significantly higher levels of concern compared to males ($p<0.001$). This is a substantially higher percentage than the 3% of physicians in previous studies who shared the same concern.¹⁵ However, concerns remain that AI algorithms may overlook subjective aspects of illness by focusing solely on objective data.¹⁶ as noted by 67% of participants who raised concerns about diagnostic accuracy, with these concerns significantly associated with recent graduates ($p=0.01$) and females ($p=0.01$). When used correctly, AI provides information to better manage eye conditions, freeing physicians for personalized care and shared decision-making. Most participants (76.7%) believe that AI should be included in optometry curricula or residency training, with residency-trained participants showing significantly greater support ($p<0.001$). AI strengths and weaknesses among providers should become established before it can be fully incorporated into practice. Increased exposure to AI during training and continuing education may strengthen positive attitudes toward the

technology. As the present literature base is sparse, curricula for the future should cover AI-related literature, critically assess their effectiveness, and evaluate real-life clinical applications.¹⁷

Approximately 48.4% of respondents agreed that AI may influence the doctor-patient relationship. This perception was significantly associated with graduation year ($p < 0.001$), with recent graduates expressing greater concern. No significant associations were observed for the remaining demographic variables (residency status, gender, or mode of practice). This reflects an ongoing debate in healthcare literature about the risk that AI-driven processes may depersonalize patient care. Patient trust is a cornerstone of optometric care, making it imperative to carefully integrate AI into patient interactions to preserve the valued interpersonal aspects of eye care.

Although several demographic variables showed statistically significant associations with AI-related perceptions, effect size estimates (Cramér's $V = 0.16-0.28$) indicated that these associations were generally small to small-moderate. Furthermore, multivariable logistic regression demonstrated that familiarity with AI, completion of residency training, and gender were independent predictors of positive perceptions toward AI in optometric practice.

The qualitative free-text responses further supported the quantitative findings. The most common theme was concern regarding diagnostic accuracy and clinical validation, which aligns with the high proportion of respondents who expressed concern about AI diagnostic reliability in the Likert-scale responses. Participants emphasized that AI should assist rather than replace clinical judgment and that optometrists must continue to retain diagnostic skills. This reflects a cautious but constructive attitude toward AI integration. Comments also highlighted practical barriers such as cost, infrastructure, and the need for training, which are particularly relevant in the Pakistani healthcare context where resource availability may vary between urban, rural, public, and private clinical settings. At the same time, several respondents recognized the potential of AI to

improve efficiency, screening, referral pathways, and access to eye care in underserved regions. These qualitative findings suggest that successful AI implementation in optometry will require not only technological validation but also professional training, infrastructure development, and clear guidelines defining the role of AI as a supportive clinical tool.

There was a significant increase in willingness to adopt AI in clinical practice following the onset of the COVID-19 pandemic, rising from 44.6% before the pandemic to 64.1% after ($p=0.02$). This finding is consistent with previous reports suggesting increased acceptance of digital health technologies after the pandemic.¹⁸ However, because the present study was cross-sectional and relied on self-reported perceptions, causality cannot be inferred. In addition, because pre-pandemic attitudes were assessed retrospectively rather than at the time, these responses are subject to recall bias, and participants' current attitudes toward AI may have shaped how they recalled their earlier views; this finding should therefore be interpreted as a perceived rather than a precisely measured change. Another study done by member of AAO also reported the increase in willingness of optometrists to integrate AI in eye care from 53% to 64% ($p<0.01$) after onset of pandemic.⁸ A pre-pandemic survey among ophthalmologists revealed near-unanimous agreement regarding the potential of telemedicine for eye care by nearly all respondents, who further considered an addition of more research in the area. During the lockdown, 98.6% of ophthalmologists expressed a strong desire to incorporate telemedicine into their practice, demonstrating the technology's capacity to bridge gaps between patients and providers during such turbulent healthcare periods.¹⁹

Many respondents perceived that AI could improve access to eye care, particularly in underserved regions, through enhanced screening, referral pathways, and tele-optometry. Similar potential applications have been described in previous studies, although additional clinical validation remains necessary before widespread

implementation. AI has significant limitations, as discussed in the previous sections, every training model of AI requires vast sets of data; the quantity and representativeness of images directly was associated with the outcome reliability. Certain medical risks are inherently associated with varying degrees of AI autonomy, ranging from assisting to fully autonomous systems, thus underlining the need for robust regulatory developments that ensure smooth integration of AI into healthcare.

Although most respondents believed that AI could enhance optometric practice, a substantial proportion expressed concerns regarding its diagnostic reliability. This finding suggests that optometrists recognize the potential benefits of AI for improving efficiency, screening, and clinical decision-making while remaining cautious about relying on AI systems for independent diagnosis. Such concerns may reflect the need for greater validation of AI algorithms, transparency in decision-making processes, and adequate professional training before widespread adoption. These findings are specific to optometrists practicing in Pakistan and may not generalize to other healthcare systems, particularly developed countries with different optometric scopes of practice, regulatory environments, or AI infrastructure. Findings may, however, be relevant to other low- and middle-income countries facing similar resource and training challenges.

Conclusion:

To conclude, optometrists participating in this study largely agreed that AI has the potential to enhance optometric practice and supported its integration into optometric education and residency training. Willingness to adopt AI increased after the COVID-19 pandemic, suggesting growing acceptance of digital health technologies. However, both quantitative responses and free-text comments highlighted persistent concerns about diagnostic reliability, possible professional displacement, implementation costs, infrastructure limitations, and the need for training. These findings suggest

that AI should be introduced as a supportive tool in optometry, accompanied by clinical validation, professional education, ethical guidelines, and regulatory oversight.

Limitations:

1. This study has several limitations. As a single survey, its findings cannot be generalized to all optometrists in Pakistan. The sample primarily includes recent graduates (2020–2024), whose perspectives might differ from experienced practitioners. Efforts were made to prevent multiple survey submissions, but some may have occurred. Of the nearly 4,000 registered optometrists in Pakistan, only 312 participated, limiting the breadth of perspectives.

2. The questionnaire used in this study was developed for the purpose of the present research and did not undergo formal psychometric validation prior to deployment. A post-hoc reliability check on the collected data found acceptable internal consistency for the four items assessing acceptance of AI integration (Cronbach's $\alpha = 0.74$), while the three items assessing distinct concerns (diagnostic accuracy, professional displacement, and impact on the doctor-patient relationship) did not form a single coherent scale (Cronbach's $\alpha = 0.47$) and were therefore analyzed as individual items rather than combined into a composite score. This post-hoc estimate offers some reassurance about the acceptance items but cannot substitute for validation conducted before data collection, since it cannot establish content or construct validity, nor rule out response biases that prospective piloting would catch. Future studies should establish the validity and reliability of the instrument prospectively, through expert content review, cognitive interviewing or pilot testing with a subset of respondents, test-retest reliability assessment, and confirmatory factor analysis of the underlying attitude dimensions; we intend to pursue this formal validation in a follow-up instrument.

3. Free-text responses were optional; therefore, the qualitative findings may reflect the views of respondents who felt more strongly about AI, either positively or negatively. In addition, the

comments were brief survey responses rather than detailed interviews, which limited the depth of qualitative exploration.

4. Only 312 of approximately 4,000 registered optometrists participated, corresponding to a response rate of approximately 7.8%, which limits the generalizability of the findings.

5. Multiple chi-square comparisons were performed across several demographic variables and outcomes without formal correction (e.g., Bonferroni). Therefore, some statistically significant findings may represent false-positive results due to inflated Type I error, and the p-values should be interpreted with caution.

6. Cramér's V was calculated for all statistically significant chi-square associations identified in this study (Table 07), yielding effect size estimates ranging from 0.16 to 0.28 (small to small-moderate effects). Effect sizes were not calculated for associations that did not reach statistical significance.

7. Willingness to adopt AI before the COVID-19 pandemic was assessed retrospectively in 2024\2013\2025, several years after the period being recalled. This retrospective design is subject to recall bias, and participants' current, generally favorable views of AI may have influenced how they recalled their pre-pandemic attitudes. The reported pre- versus post-pandemic difference should therefore be interpreted as an indication of perceived change rather than a precise measure of actual change over time.

Recommendation:

1. Implement specialized AI training programs for optometrists and eye care practitioners.
2. Integrate AI-related content into optometry curricula and residency programs.
3. Ensure clinical validation of AI tools before routine use in optometric practice.
4. Develop ethical, legal, and regulatory guidelines for AI-assisted eye care.
5. Invest in infrastructure for AI-supported screening and tele-optometry, especially in underserved and rural regions.

6. Provide financial support, grants, or institutional incentives to support AI adoption in clinical settings.

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DATA AVAILABILITY

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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