

# Attitudes of Medical Workers Toward Artificial Intelligence in Ophthalmology: A Comparative Survey

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## Research article

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# Abstract

**Background:** In the development of artificial intelligence in ophthalmology, the ophthalmic AI-related recognition issues are prominent, but there is a lack of research into people's familiarity with and their attitudes toward ophthalmic AI. This survey aims to assess medical workers' and other professional technicians' familiarity with, attitudes toward, and concerns about AI in ophthalmology.

**Methods:** An electronic questionnaire was designed through the app Questionnaire Star, and was sent to participants through WeChat, China's version of Facebook or WhatsApp. The participation was voluntary and anonymous. The questionnaire consisted of four parts, namely the participant's background, their basic understanding of AI, their attitudes toward AI, and their concerns about AI. A total of 562 participants were counted, with 562 valid questionnaires returned. The results of the questionnaires are displayed in an Excel 2003 form.

**Results:** A total of 562 participants completed the questionnaire, of whom 291 were medical workers and 271 were other professional technicians. About 1/3 of the participants understood AI and ophthalmic AI. The percentages of people who understood ophthalmic AI among medical workers and other professional technicians were about 42.61% and 15.6%, respectively. About 66.01% of the participants thought that AI in ophthalmology would partly replace doctors, with about 59.07% still having a relatively high acceptance level of ophthalmic AI. Meanwhile, among those with AI in ophthalmology application experiences (30.6%), above 70% of participants held a full acceptance attitude toward AI in ophthalmology. The participants expressed medical ethics concerns about AI in ophthalmology. And among the participants who understood AI in ophthalmology, almost all the people said that there was a need to increase the study of medical ethics issues in the ophthalmic AI field.

**Conclusions:** The survey results revealed that the medical workers had a higher understanding level of AI in ophthalmology than other professional technicians, making it necessary to popularize ophthalmic AI education among other professional technicians. Most of the participants did not have any experience in ophthalmic AI but generally had a relatively high acceptance level of AI in ophthalmology, and there was a need to strengthen research into medical ethics issues of the field.

## Background

In recent years, with the increase of computational speed, neural networks have regained prosperity after hitting its rock bottom. The deep convolutional neural network AlexNet [1] winning the first place in the ImageNet competition has led to the rapid development of deep learning technology. After that, deep learning network models [2–10] have emerged generation after generation, which has accelerated the development of artificial intelligence (AI) technology. Through AI, researchers can make the preliminary diagnosis of skin cancers, achieve rapid intraoperative diagnosis of brain tumors, diagnose 55 common diseases in pediatrics based on electronic medical records in Chinese, identify rare genetic diseases through facial photographs, and generate the findings that early and frequent patient movements can

reduce the risk of post-intensive care syndrome and long-term dysfunction after analyzing patients' movement activities in the intensive care units. [11–15]

Medical instruments are frequently used in clinical examinations in modern medicine, and imaging equipment is an important part. Imaging equipment is used for X-ray imaging, magnetic resonance imaging, ultrasound imaging, tomography imaging, and fundus photography, etc. The data in the ophthalmology field are both in a wide variety and in large quantities, among which the most common types are fundus photographs and optical coherence tomography (OCT) images, making it the most extensively researched field with AI. Fundus photography and OCT are regular examinations used in ophthalmology, through which a vast amount of high-quality standard images can be obtained. These images are suitable for analysis and process by AI deep learning technology to further assist doctors in diagnosing ophthalmopathies. Using deep learning technology in AI, Google researchers have created an algorithm that can detect diabetic retinopathy and macular edema. By analyzing human retinal images, this algorithm can very accurately predict risk factors affecting cardiovascular health. [16–17] The researchers from Sun Yat-sen University in China have developed a deep learning model called CC-Cruiser for recognizing congenital cataract, which is also able to diagnose blinding diseases such as age-related macular degeneration and diabetic macular edema after trained with deep learning algorithms based on OCT images [18–19]. Besides, there are related studies that use AI technology for the segmentation of ophthalmic images [20–21], and the classification of ophthalmopathies [22–24], etc.

Artificial intelligence technology has been studied so extensively in ophthalmology that some even have been on the commercializing stage [25], thus leading to some people believing that AI may be able to replace doctors. Some researchers investigated the attitudes of medical undergraduates to the application of AI in radiology and medicine [26], the attitudes of medical students in other regions to AI [27], the influence of artificial intelligence on radiology [28], as well as how to cope with the ethical challenges in medical AI [29–30], etc. However, few people know about medical workers' familiarity with and their attitudes toward AI in ophthalmology. For this purpose, a questionnaire was designed to assess medical workers' (health care workers or medical students) understanding level of and their attitudes toward AI. Meanwhile, the questionnaire also surveyed other professional technicians using the same questions as a comparison.

The survey of AI in ophthalmology-related questions cannot only evaluate the attitudes of medical workers (health care workers or medical students) and other professional technicians toward AI and clarify the dilemma facing the current technological development, it can also provide theoretical guidance for its future practice and application. At present, in the development of AI in ophthalmology, there are a lot of existing and foreseeable medical ethical problems. Analysis of the causes of these problems through this survey may help to put forward corresponding countermeasures so that we can draw on advantages and avoid disadvantages in the future development of AI in ophthalmology.

## Methods

Using the Questionnaire Star APP, we designed an electronic questionnaire that consisted of four parts. The first part was the participant's basic information, including the participant's gender, age, educational level, place of residence, work area and professional title; the second part was about the participant's basic understanding of AI, including whether the participant understood AI, medical AI, and AI in ophthalmology, as well as the participant's evaluation of the current development of AI in ophthalmology; the third part was about the participant's attitude to AI, including whether he/she thought AI in ophthalmology would replace doctors, whether he/she had experience in AI in ophthalmology application, and his/her acceptance level of AI in ophthalmology; and the fourth part was about the participant's concerns about AI, which included the participant's specific concerns about AI in ophthalmology and whether he/she thought it was necessary to strengthen medical ethics research in the field.

Participants of the questionnaire were mainly members of the Zhejiang Society of Mathematical Medicine, with their locations covering various cities and counties mainly in Zhejiang Province. They worked as ophthalmologists, medical students, AI technicians, and professional technicians in other fields. Their educational levels were above junior high school and could understand the questionnaire well. The questions in the questionnaire have been investigated, sorted and summarized repeatedly in a broad and deep way. The survey is a targeted group survey. Questionnaires were sent to medical workers through professional ophthalmological or medical intelligence groups and other professionals through related professional groups. Before we collect the questionnaires for statistical analysis, each participant was invited to fill out the questionnaire once based on a voluntary and anonymous principle and was informed that the results of the survey would be further used for statistical assessment and publication. A total of 562 participants were counted, with 562 valid questionnaires returned. The results of the questionnaires are displayed in an Excel 2003 form.

According to the Article 3 of the Measures for the Ethical Review of Biomedical Research Involving Humans issued by the National Health and Family Planning Commission in 2016, ethical review is unnecessary for the study.

## Results

### Basic information of participants

Of the 562 participants, 291 were medical workers (51.78%) with the rest being other professional technicians (48.22%). Nearly half of them were from prefecture-level cities (47.69%), about 1/4 (24.91%) were from provincial capital cities, and the remaining were from other regions (27.41%). 9.96% had a doctor's degree or higher education, 12.99% had a master's degree, and 77.05% had a bachelor's degree or lower education; 31.49% had senior titles, 25.44% were with intermediate titles, and 32.03% were primary and ungraded professionals. The complex structure of these participants had relatively good social representative value.

### Participants' basic understanding of artificial intelligence

The percentage of participants who completely understood and almost understood AI was 37.9%, who understood a little was 52.14%, and who didn't understand AI was 9.96%; the percentage of participants who completely understood and almost understood medical AI was 31.67%, who understood a little was 44.31% and who didn't understand medical AI was 24.02%; the percentage of participants who completely understood and almost understood AI in ophthalmology was 29.54%, who understood a little was 34.52%, and who didn't understand AI in ophthalmology was 35.94%. That is to say, the number of participants whose understanding level of AI, medical AI, and AI in ophthalmology was "completely", "almost" or "a little" was gradually decreasing in the mentioned order (AI, medical AI, and ophthalmological AI), while the number of people who did not know about AI, medical AI, and AI in ophthalmology was gradually increasing in the same order.

Among the participants, 19.4% thought that the current development of AI in ophthalmology was very good. 42.7% thought that its current development was good. 35.23% thought that its current development was average. While the remaining 2.67% thought that the development level was poor. Therefore, the vast majority of the participants held a positive or wait-and-see attitude toward the current development of AI in ophthalmology, with a few others having a negative attitude.

Table 3, Fig. 1, Fig. 2, and Fig. 3 show that the numbers of medical workers whose understanding level was "almost understand" or above (including "completely understand" and "almost understand") were 47.42%, 45.02%, and 42.61%, respectively, for AI, medical AI, and AI in ophthalmology. For other professional technicians, the numbers were 27.68%, 17.35%, and 15.5%, respectively. For the two different groups by working fields, the participants' understanding level of AI, medical AI, and AI in ophthalmology tended to drop in the mentioned order. But the number of people whose understanding level of these three AIs was "almost understand" and above was greater among medical workers than among other professional technicians. Artificial intelligence is relatively well popularized in the medical field, meanwhile, there is a need to enhance the popularization of artificial intelligence-related knowledge among people in other fields.

Table 1  
Participants' basic information (N = 562).

Characteristic	Participants
<b>Gender, n(%)</b>	
Male	216(38.43)
Female	346(61.57)
<b>Age (years), n(%)</b>	
25 or less	70(12.46)
25–45	340(60.5)
45 or more	152(27.05)
<b>Work area, n(%)</b>	
Medical worker (health care worker or medical student)	291(51.78)
Other professional technicians	271(48.22)
<b>Place of residence, n(%)</b>	
Provincial capital	140(24.91)
Prefecture-level city	268(47.69)
County and below	152(27.05)
Abroad	2(0.36)
<b>Education, n(%)</b>	
Doctor and above	56(9.96)
Master	73(12.99)
Bachelor	244(43.42)
Other lower education	189(33.63)
<b>Professional title, n(%)</b>	
Ungraded	180(32.03)
Primary	62(11.03)
Intermediate	143(25.44)
Senior	177(31.49)

Table 2  
Participants' basic understanding of artificial intelligence (N = 562).

Understanding level	Value
<b>Artificial intelligence, n(%)</b>	
Completely	39(6.94)
Almost	174(30.96)
A little	293(52.14)
Not understand	56(9.96)
<b>Medical artificial intelligence, n(%)</b>	
Completely	33(5.87)
Almost	145(25.8)
A little	249(44.31)
Not understand	135(24.02)
<b>Ophthalmic artificial intelligence, n(%)</b>	
Completely	34(6.05)
Almost	132(23.49)
A little	194(34.52)
Not understand	202(35.94)
<b>Current development of ophthalmic artificial intelligence, n(%)</b>	
Very good	109(19.4)
Good	240(42.7)
Average	198(35.23)
Poor	15(2.67)

Table 3  
Medical workers and other professional technicians ' basic understanding of artificial intelligence (N1 = 291, N2 = 271).

Understanding level	Value1	Value2
<b>Artificial intelligence, n(%)</b>		
Completely	17(5.84)	22(8.12)
Almost	121(41.58)	53(19.56)
A little	140(48.11)	153(56.46)
Not understand	13(4.47)	43(15.86)
<b>Medical artificial intelligence, n(%)</b>		
Completely	18(6.19)	15(5.54)
Almost	113(38.83)	32(11.81)
A little	132(45.36)	117(43.17)
Not understand	28(9.62)	107(39.48)
<b>Ophthalmic artificial intelligence, n(%)</b>		
Completely	19(6.53)	15(5.54)
Almost	105(36.08)	27(9.96)
A little	121(41.58)	73(26.94)
Not understand	46(15.81)	156(57.56)

As is shown in Fig. 4, about 71% of medical workers and 53% of other professional technicians believed that the current development of AI in ophthalmology was good; while among those who completely understood and almost understood AI in ophthalmology, about 81% of medical workers and 76% of other professional technicians thought that the current development of AI in ophthalmology was good.

## Participants' attitudes toward artificial intelligence



In Table 4, on the question of whether AI in ophthalmology would replace doctors, 24.02% of participants said no. But 66.01% thought it would partly replace doctors, and 1.78% thought that AI in ophthalmology had a bright prospect and would completely replace doctors. As is shown in Fig. 6, about 97% of medical workers and 85% of other professional technicians believed that AI in ophthalmology would partly or would not replace doctors, suggesting that the participants, while acknowledging AI in ophthalmology, also recognized the value of ophthalmologists.

Table 4  
Participants' attitudes toward artificial intelligence (N = 562).

<b>AI in ophthalmology will replace ophthalmologists, n(%)</b>	
Completely	10(1.78)
Partly	371(66.01)
Not	135(24.02)
Don't understand	46(8.19)
<b>Do you have any experience with AI in ophthalmology?, n(%)</b>	
Being using or about to use	29(5.16)
Having applied	49(8.72)
Having experienced	94(16.73)
Having no related experience	390(69.4)
<b>Acceptance level of AI in ophthalmology, n(%)</b>	
Completely	332(59.07)
Partly	218(38.79)
Not accept	10(1.78)
Strongly resist	2(0.36)

69.4% of the participants had no ophthalmic AI-related experience while the rest had applied or experienced AI in ophthalmology. As is shown in Fig. 7, 56.36% of medical workers and 83.39% of other professional technicians had no experience in the application of AI in ophthalmology, indicating that while developing rapidly, AI in ophthalmology hasn't been widely used.

59.07% of the participants had a relatively high acceptance level of AI in ophthalmology, with only 2.14% against it. As is shown in Fig. 8, among those with experience in the application of AI in ophthalmology, 84.25% of medical workers and 73.33% of other professional technicians would fully accept it.

## Participants' concerns about artificial intelligence

In Table 5, among the participants, 56.41% said that in the current ophthalmic AI practice, medical responsibilities are unclear; 49.29% said that the quality of AI in ophthalmology services was difficult to guarantee; while the percentage of those who thought there existed problems such as extreme high prices, medical ethical risks and lack of political support was about 40%. More than 90% of the participants thought there was a need to strengthen medical ethics research in the ophthalmic AI field. Among those who completely and almost understood AI in ophthalmology, 98.39% of medical workers and 95.24% of other professional technicians believed it was necessary to strengthen medical ethics research in the field, as is shown in Fig. 9. This is enough to showcase the importance of addressing medical ethical issues in the ophthalmic AI field.

Table 5  
Participants' concerns about artificial intelligence (N = 562).

<b>What are your concerns about AI in ophthalmology? (multiple selection), n(%)</b>	
Medical responsibilities are unclear	317(56.41)
Service price is too expensive	252(44.84)
Service quality is difficult to guarantee	277(49.29)
Medical ethical risk	240(42.7)
Policy support may not be in place	235(41.81)
Others	85(15.12)
<b>Is it necessary to strengthen the study of medical ethics in the ophthalmic AI field?, n(%)</b>	
Yes	517(91.99)
No	45(8.01)

## Discussion

In the survey, the number of medical workers participated was roughly equal to that of other professional technicians. The proportion of participants who did not understand AI among other professional technicians was about three times that of medical workers. And the proportion of those who didn't understand medical AI among other professional technicians was about 4 times that of medical workers. The proportion of people who did not understand AI in ophthalmology among other professional technicians was about four times that of medical workers. Hence one can see that the understanding level of AI, medical AI, and ophthalmic AI among the medical workers who participated in the survey is higher than that among other professional technicians, suggesting that in China, AI is relatively more widely popularized among medical workers. In recent years, AI has been more and more widely introduced in the medical field. Due to work or academic exchanges, medical workers have more

opportunities to learn about medical AI than other professional technicians. The other professional technicians in this survey were technical personnel whose research areas had no connection to medicine or AI. As a result, they had relatively less knowledge about medical AI and fewer opportunities to apply or experience medical AI, especially in the more specialized clinical ophthalmology field. Naturally, those in the survey who had no medical background would have a difficult time imagining the application of AI in medicine. Therefore, the real-life application of AI in other areas should be further popularized in our society to gain more of people's trust before AI can be used in medical care.

Concerning the attitudes toward AI, both medical workers and other professional technicians were relatively confident in human doctors, with only a very small number of people thinking that AI in ophthalmology would completely replace ophthalmologists. Most participants were relatively rational, believing that ophthalmic AI would only partly replace ophthalmologists. As people become more rational about AI in ophthalmology, the condition has been more and more favorable for the healthy development of AI in the medical field. As suggested by Turing for the healthy development of AI, "Instead of trying to produce a program to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain." [31] This conception has functioned as guidance in the research of medical AI. Whether it's Nature's publication of AI used for DR diagnosis or the U.S. Food and Drug Administration's approval of IDx-DR in 2018 [25], there has been no real diagnostic systems that can fully diagnose and identify all the 4 grades of DR, which means there is still a long way for ophthalmic AI to go from laboratory research to clinical application. But undeniably, in a country such as China where ophthalmologists are in much dire need (the over 1.4 billion Chinese people only share about 36,000 ophthalmologists), the application of AI can help to diagnose and treat many more patients, which would reduce the burden on ophthalmologists, thus probably having led to the higher acceptance level of ophthalmic AI among medical workers. Meanwhile, those other professional technicians, despite a relatively lower understanding level, also basically held a positive attitude to acknowledging AI in ophthalmology.

As far as the application of ophthalmic AI goes, there are currently some pilot centers in China that provide opportunities to experience its real-life application. However, due to the rarity of such centers, only close to half of the medical workers involved in the survey had related experience while 4/5 of the other professional technicians had no such experience. This indicates that the application of AI in ophthalmology is not yet popularized. It has very few real-life applications, mainly due to technical and ethical issues. On the technical side, the systems that had relatively good diagnosing abilities turned out to be not well performed in the complex real-life scenarios, requiring further improvement. And on the ethics side, the medical responsibilities are not clearly defined for the artificial intelligence diagnostic systems and there are no related policies to follow or to regulate it with. Therefore, although the research of AI in ophthalmology is going well, it still takes prudence in its real-life application.

In recent years, the application of AI in ophthalmology is very deeply researched, but there are not so many studies on related policies and ethics. The survey found that unclear medical responsibilities and difficulty in guaranteeing service quality respectively ranked as the No. 1 and No. 2 concerns about the

use of AI in ophthalmology, with 60% of the participants worrying about the "unclear medical responsibilities." These concerns are sufficient to show that the country needs to improve its regulation system of AI and strengthen the exploration of relevant medical ethics issues. Only when the relevant regulation system and ethics issues have been addressed can we guarantee the real-life practice of medical AI, and establish people's confidence in medical AI so that they can truly accept its relevant application.

The survey mainly analyzed the participants' understanding and acceptance level of AI in ophthalmology, as well as the participants' concerns about AI in ophthalmology. The participants in this survey are mainly from Zhejiang, China, an important part of the Yangtze River Delta, which is one of china's relatively developed regions. With almost no participants from remote areas, the survey results do not represent those of medical workers and other professional technicians nationwide. Besides, although the participants are relatively evenly distributed among the different groups, the total number is relatively small. That is to say, the follow-up surveys should try to broaden the survey scope, making the findings more credible and broadly representative.

## Conclusions

The survey results revealed that the medical workers had a higher understanding level of AI in ophthalmology than other professional technicians, making it necessary to popularize ophthalmic AI education among other professional technicians. Most of the participants did not have any experience in ophthalmic AI, but generally had a relatively high acceptance level of AI in ophthalmology, and there was a need to strengthen research into the medical ethics issues of the field.

## Abbreviations

AI  
artificial intelligence  
OCT  
optical coherence tomography  
DR  
diabetic retinopathy

## Declarations

## Ethics approval and consent to participate

In China, the National Health and Family Planning Commission officially issued Measures for the Ethical Review of Biomedical Research Involving Humans in 2016. The Article 3 defines the biomedical research involving human subjects.

Article 3. Biomedical research involving human subjects in the Measures includes:

(1) activities of conducting research on human physiology, psychological behavior, pathological phenomena, causes and pathogenesis of diseases, as well as the prevention, diagnosis, treatment and rehabilitation of diseases, using modern methods in physics, chemistry, biology, traditional Chinese medicine and psychology, etc.;

(2) activities of experimental research on the human body of new medical technologies or new medical products;

(3) activities in which scientific research materials such as specimens, medical records and behaviors relating to humans are collected, recorded, used, reported or stored by epidemiological, sociological and psychological methods.

This study mainly investigates people's current understanding of the cross field application of artificial intelligence in medicine, which does not involve the activities stipulated in Article 3 of the censorship measures. Thus ethical review is not required for the study.

Participants were informed verbally as well as in written form in the questionnaire that completing and submitting the questionnaire meant they agreed to participate in the study.

## **Consent for publications**

Participants were verbally informed that the results of the survey would be further used for statistical assessment and publication, which is also clearly stated in written form in the questionnaire.

## **Availability of data and materials**

All data generated or analyzed during this study are included in this published article.

## **Competing interests**

The authors declared no competing interests.

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The Natural Science Foundation of Zhejiang Province (LQ18F020002) mainly studies DR images labeling and diagnosis based on it. The Zhejiang Basic Public Welfare Research Program (LGF18H120003) mainly studies intelligent diagnostic systems of DR. The National Natural Science Foundation of China (61906066) mainly studies vision prediction after cataract surgery. The Zhejiang Medical and Health Research Project (2018270516) and the Huzhou Science and Technology Planning Program (2019YSR23) mainly study the cross field application and promotion of artificial intelligence and ophthalmological diagnostic technologies. All the above foundations focus on the cross field application

of artificial intelligence in medicine (especially in ophthalmology) and need to know about people's knowledge of artificial intelligence, artificial intelligence in medicine and artificial intelligence in ophthalmology, which is why the support for the study.

## Authors' contributions

During the study, all authors have contributed significantly. WY and BZ, FF analyzed data and drafted the manuscript. MW and SZ, HZ analyzed data and revised the draft. WY, BZ, MW, XH, YJ and JW designed electronic questionnaire. WY, BZ, MW, XH, and XP sent the questionnaire to participants. WY and XP designed the experiment and built initial constructs. WY, BZ and XP together proposed the idea and supervised the project.

All authors have read and approved the manuscript.

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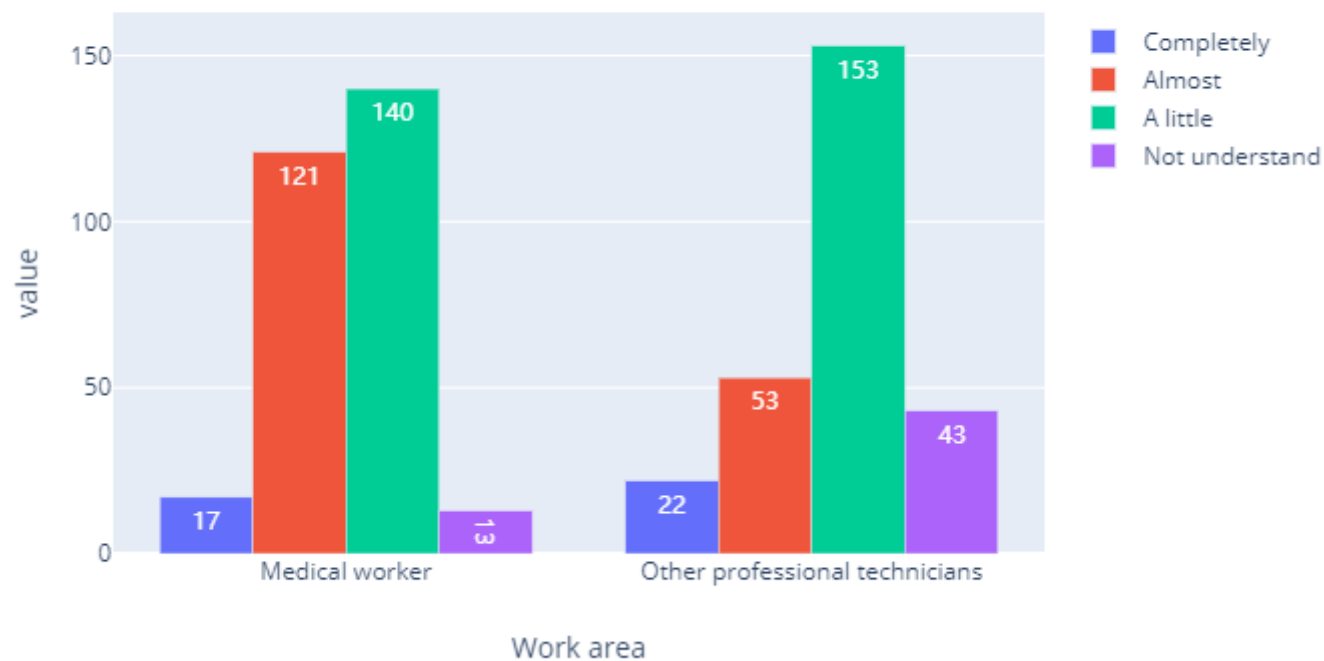
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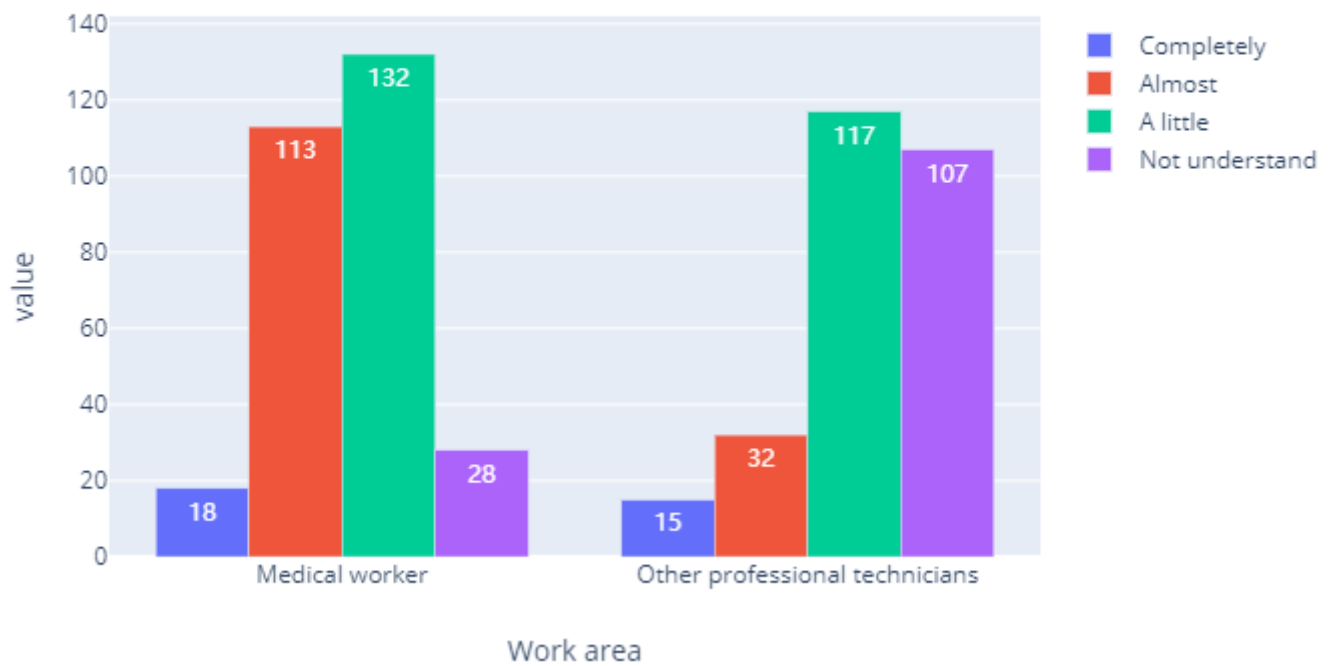
Figures



**Figure 1**

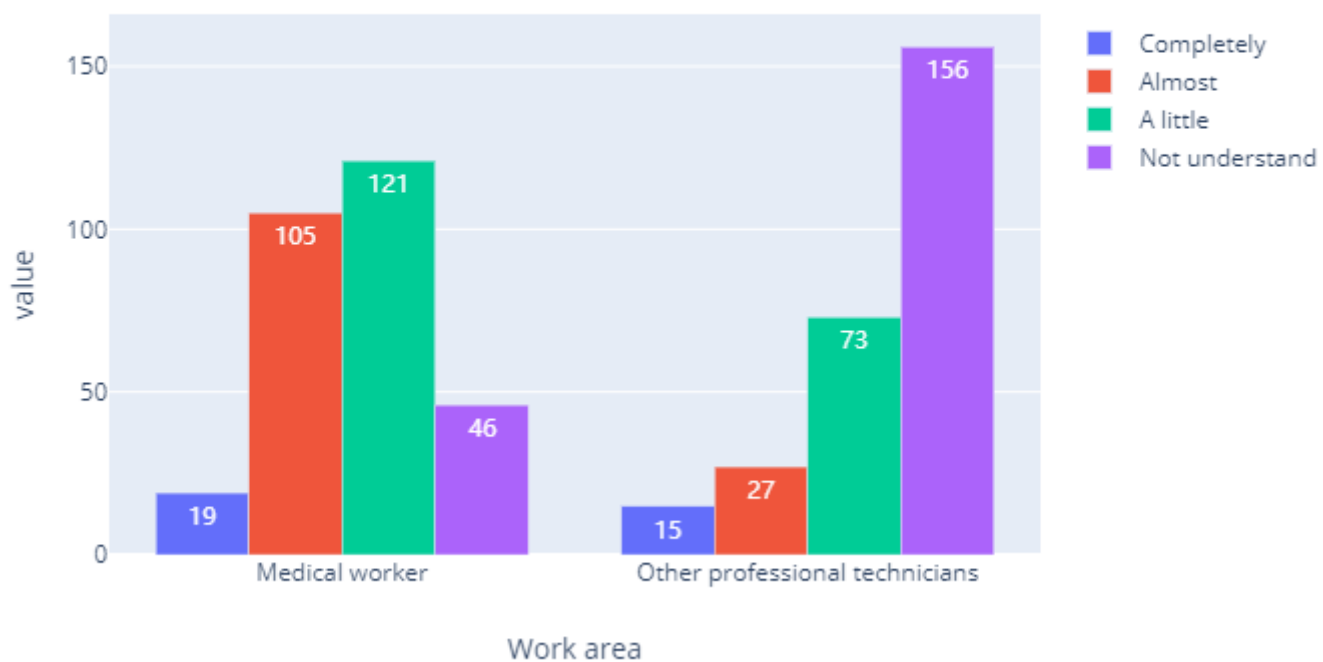
Participants' understanding level of artificial intelligence.





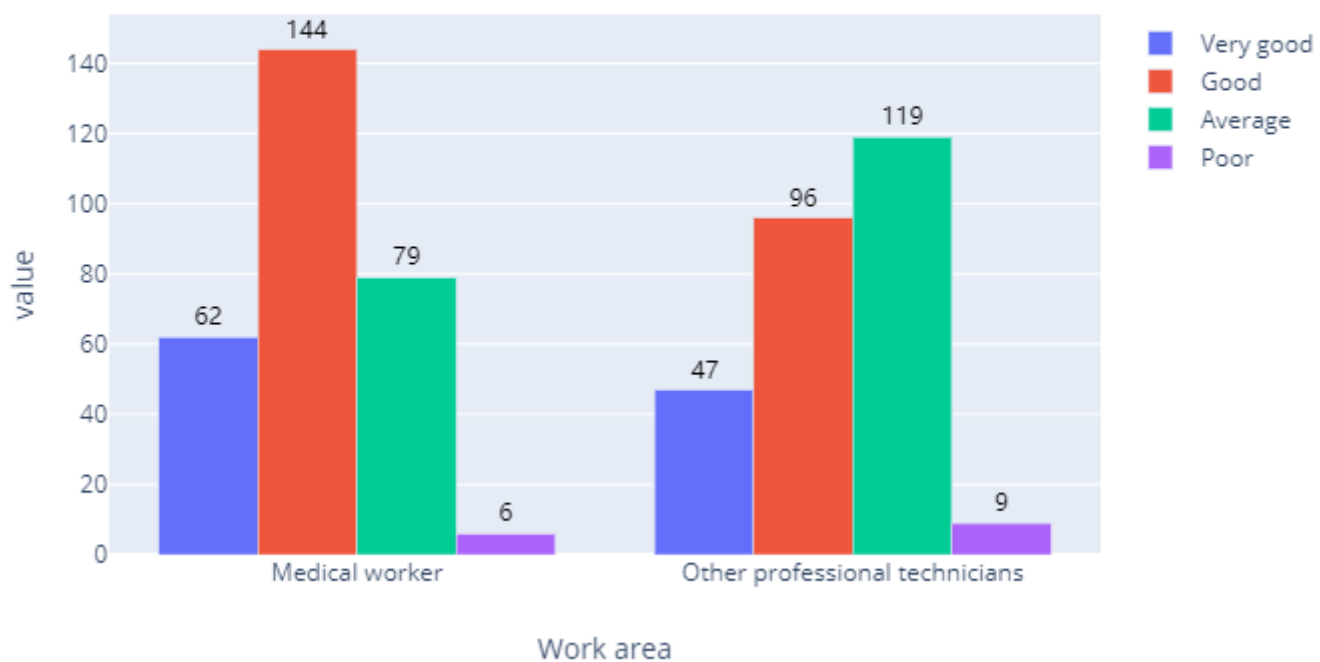
**Figure 2**

Participants' understanding level of medical artificial intelligence.



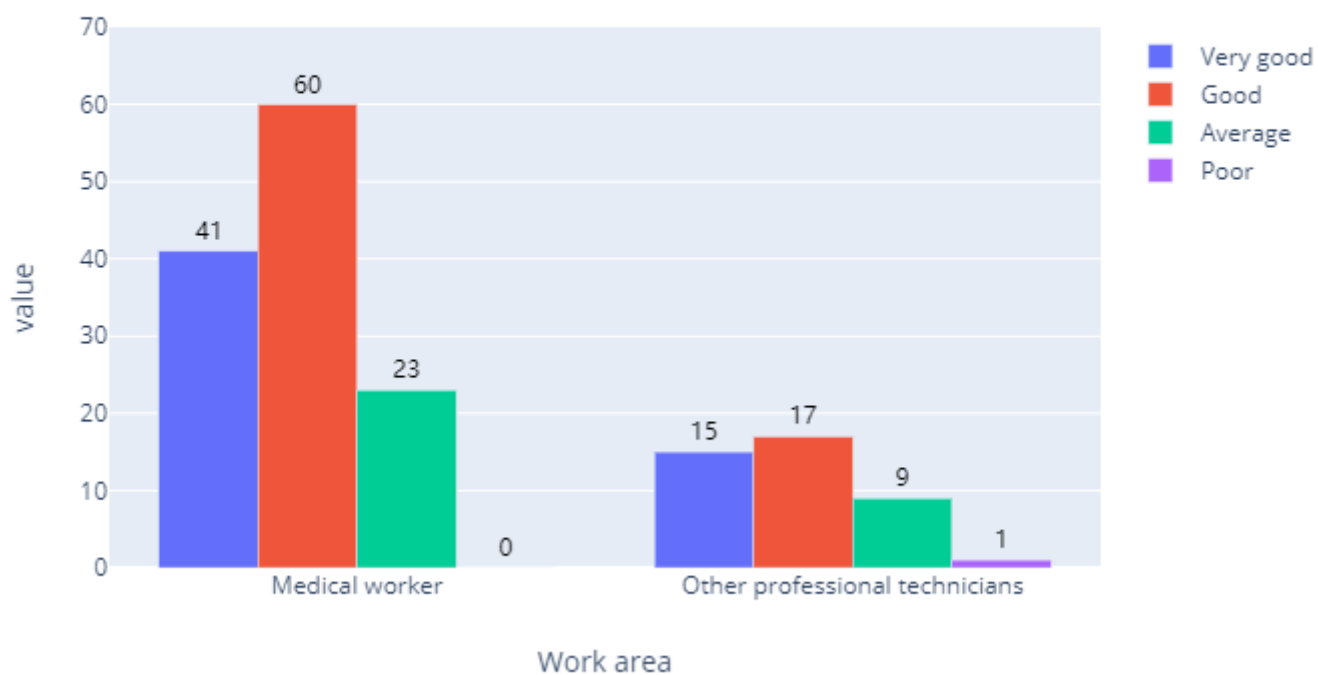
**Figure 3**

Participants' understanding level of ophthalmic artificial intelligence.



**Figure 4**

Participants' evaluation of the current development level of artificial intelligence.



**Figure 5**

Evaluation of the current development level of artificial intelligence of the participants who completely and almost understood artificial intelligence.

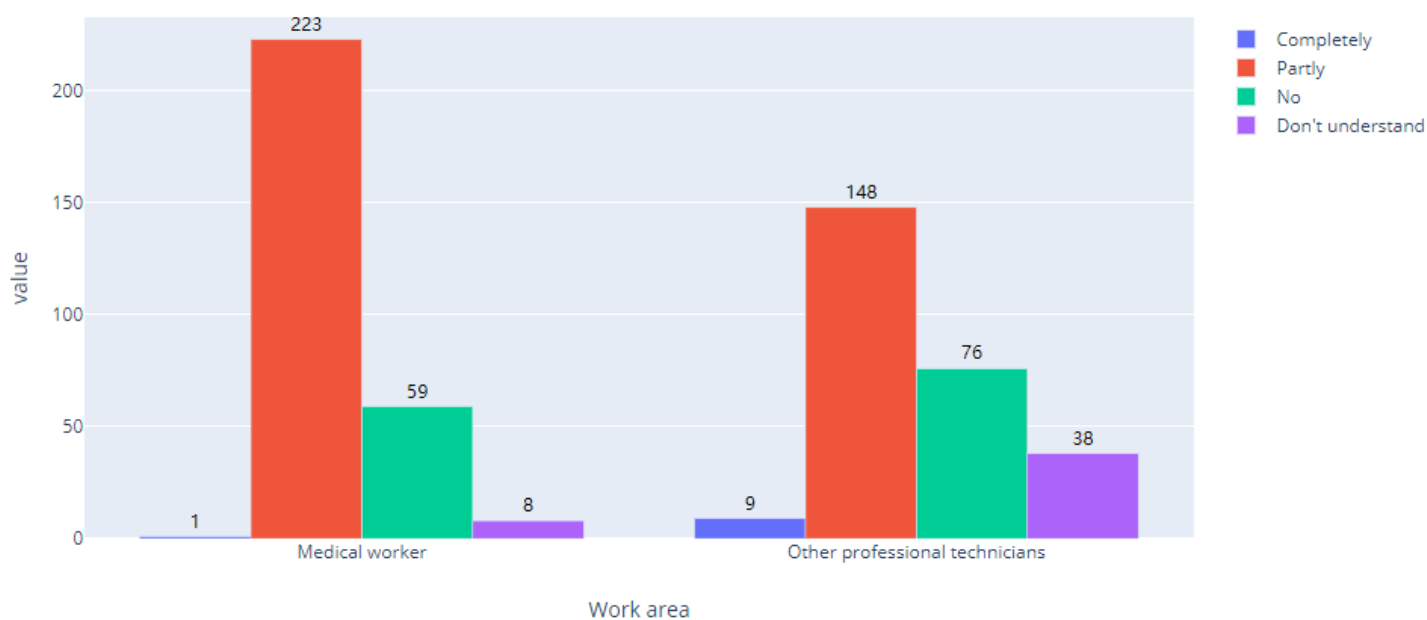


Figure 6

Participants’ prediction on the extent to which ophthalmic artificial intelligence would replace doctors.

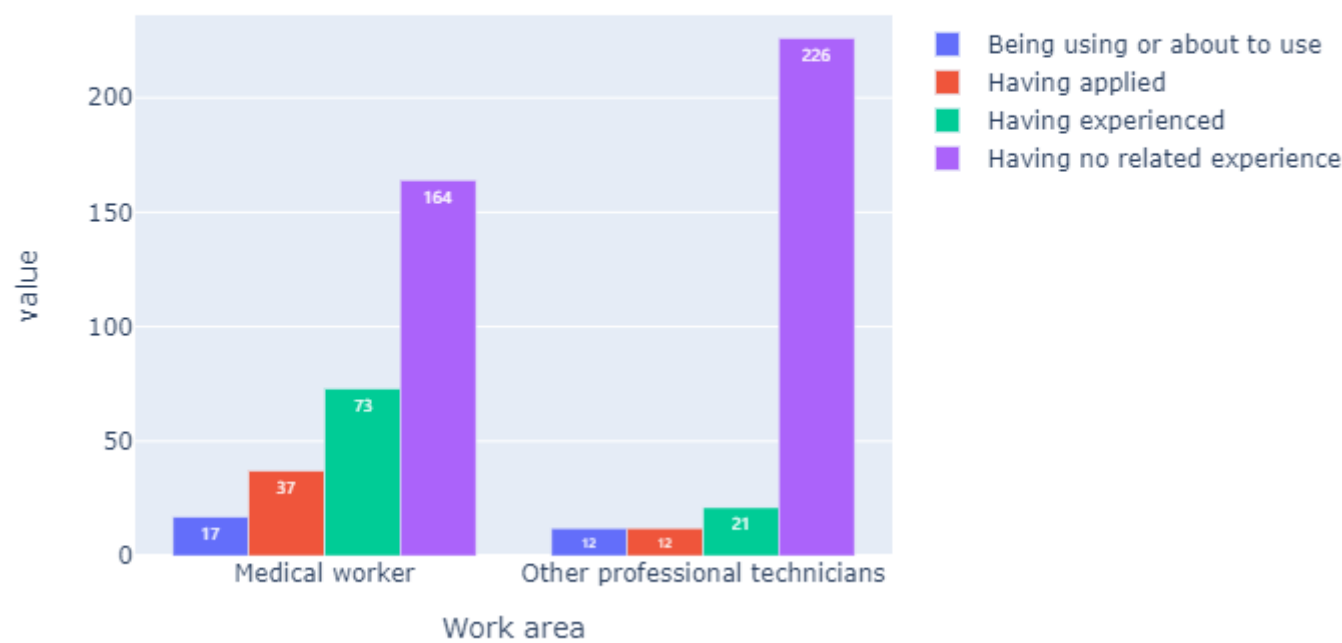
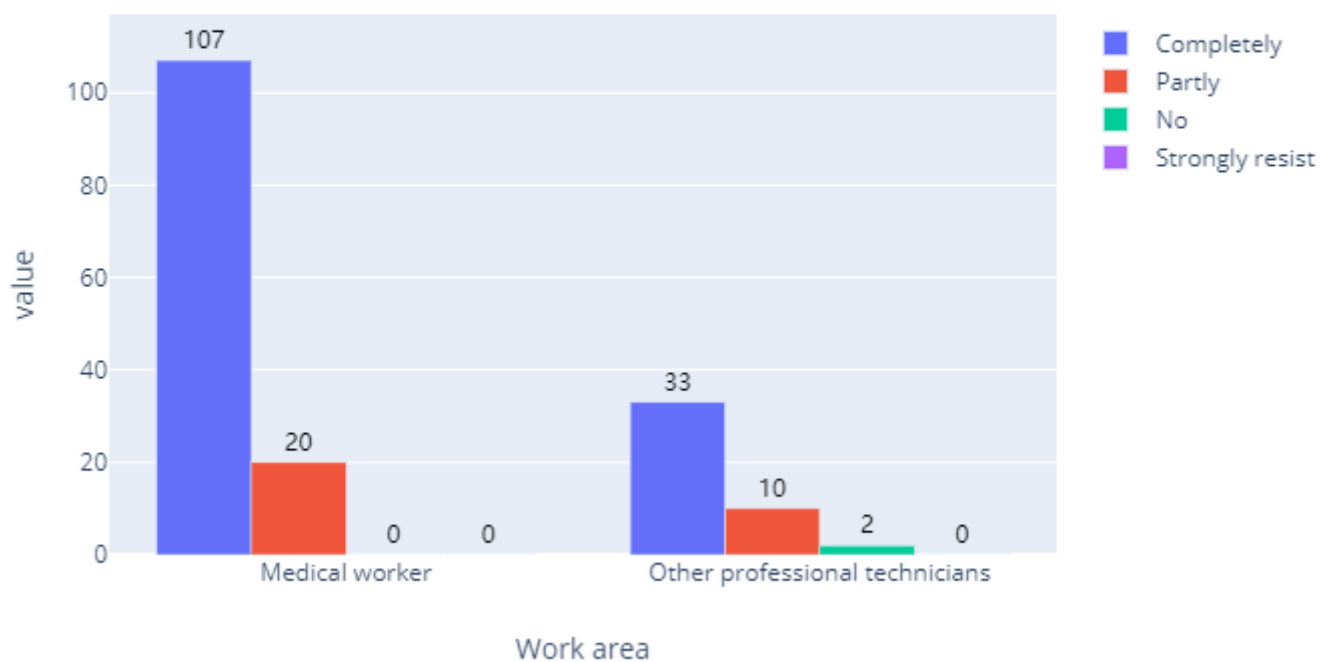


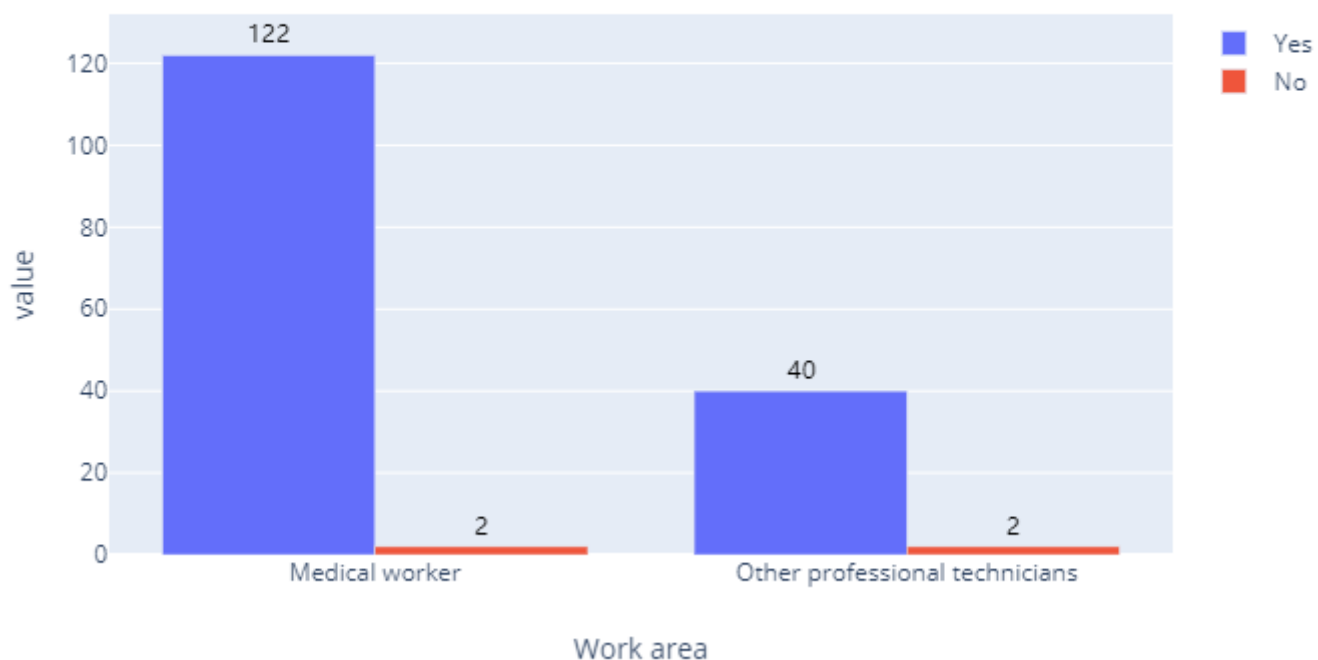
Figure 7

Participants’ experience in the application of ophthalmic artificial intelligence.



**Figure 8**

Acceptance level of ophthalmic artificial intelligence among the participants who had experience in ophthalmic artificial intelligence.



**Figure 9**

Attitudes of the participants whose understanding level was “almost understand” or above toward the question.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [OphthalmologyArtificialIntelligenceQuestionnaireSurvey.docx](#)