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The Impact on Healthcare Service Quality and Patients Satisfaction *via* Adopting Mobile Health Technology: An empirical Study in a Public Ophthalmologic Hospital in China

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ABSTRACT

Background and objectives: The main issues should be solved in Chinese hospital management process are illustrated as long registration time and waiting list, extensive prescription dealing period and short duration of General Practitioner consultation. In order to improve healthcare process and patients' satisfactory level, a large amount of hospitals is engaging in developing mobile health applications. However, the research on the impact of mobile health applications use (MHAU) on patients' satisfactory level and treatment quality are quite few. This research is concentrated on evaluating patients' satisfaction and healthcare service quality *via* empirical analysis.

Methods: We established one model based on literature review, which related to MHAU, clinical process change perceived by patient, service quality, and patient satisfaction. Additionally, the mature scale were selected and revised as a survey instrument in this study, and was conducted at Shenzhen Ophthalmic Hospital using a paper questionnaire. In terms of the survey, patients are randomly selected to fill out the form during December 2018 to January 2019. Further, the research model and hypotheses has been verified with assistance of regression analysis.

Results: The results demonstrated that the MHAU on the patient's satisfaction is significant and direct (b=0.162, p=0.000<0.01), rather than on the service quality of hospital (b=-0.011, p=0.665). Additionally, the initial effect of MHAU is on the clinical process change perceived by patient (b=0.456, p=0.000<0.01), and then the effect will extend the service quality of hospital (b=0.316, p=0.000<0.01). The physician-patient interaction is an important factor that positively affects the service quality of hospital (b=0.342, p=0.000<0.01). Meanwhile, convenience is another important factor for patients to consider the service quality of hospital, and it has a positive and significant impact on patient satisfaction (b=0.120, p=0.000<0.01).

Conclusion: Hospital managers should not only pay attention to the management of system usage, but also to organizational factors that affect the results of system usage, such as the clinical process change perceived by patients. The dimension of convenience should be considered when evaluating the service quality of hospital, especially for large hospitals with large outpatient service. In addition, the managers should pay attention to enhancing the initiative of physician-patient interaction, as it is an important factor affecting patients' perception of the services quality. This study provides a reference for investigations in ophthalmic hospital scene and needs to be confirmed further in other hospital scenarios.

Keywords: Service quality; Patient satisfaction; Mobile health apps use; Doctor-Patient relationship

Note: # indicates as equal contribution as corresponding author.

INTRODUCTION

Due to the huge population and lack of medical resources in current China, crowed and disorder hospital management usually makes the patients to experience the terrible clinical process, such as spending massive time checking in, queuing for payment, waiting for medical treatment etc., which easily rises up high conflicts of doctor-patient relationship and low service quality perception by patient [1,2]. As presented on China Internet Network Information Center latest version [3]. China's Internet users have reached 854 million, meanwhile, mobile phone users have reached 847 million. Most of Chinese hospitals began to encourage patients to use mobile health technologies or applications (apps) for purpose of improving experience of the healthcare process, hospital service quality perception and patient satisfaction. Most of apps are designed for patients to download in their cell phones or tablet computers. In this way, the patients can access to information about the hospital and its medical practitioners, as well as consult, book and pay through mobile platforms. In terms of hospital management era, it will be an important manner for improving patient service quality perception and satisfaction.

In ophthalmologic hospital settings, there are a few studies regarding to the adoption and perception of health information technologies, such as electronic health records (EHRs) by ophthalmologists. In general, the adoption rate of EHRs is high in ophthalmological hospitals [4-6]. Although the EHRs is relatively low compared with that in other specialized hospitals [7], the results of the efficiency of workflow caused by EHRs use have not been consistently agreed by all researchers [4-6,8]. Therefore, current literature does not involve any studies related to the effect of the mobile health apps use (MHAU) on service quality and patient satisfaction in ophthalmic hospitals. Furthermore, in other specialized or general hospitals settings, there is some conflicts and uncertainty about the mechanism by which patients using mobile health technologies to perceive service quality.

Therefore, this study focuses on exploring the impact of MHAU on patient satisfaction levels, in order to play the leading role of MHAU in promoting higher service quality levels in ophthalmologic hospitals. Specifically, according to the mobile health technologies and service quality literature, this study proposes that MHAU positively impacts patient satisfaction levels, while, MHAU actively drives clinical process change perceived by patient, and that has a positive impact on the service quality. Then, the three key factors impacting the MHAU levels were identified according to the literature of mobile health technologies, clinical process change perceived by patients, information accessibility, and physician-patient interaction. We initiated a survey of the patients at the Shenzhen ophthalmological Hospital between December 2018 and January 2019, and 618 validated questionnaires were collected, and the results support the research hypothesis presented, thus providing empirical support for the influence of MHAU and clinical process change perceived by patient on the patient satisfaction levels. The theoretical contributions of this study are included in two main points the first is to explore MHAU on clinical process change perceived by patient and its two dimensions (information accessibility and physician-patient interaction), enhance

the digital age for the importance of MHAU, and for how mobile health technologies leading hospital digital innovation provides a theoretical explanation. The second is identified the key factors affecting patient satisfaction, for MHAU how to improve its patient satisfaction provides valuable theoretical and practical guidance.

THEORETICAL BASIS

Using Health Information Technologies

It should be emphasized that hospital service quality dimensions are various in different scenarios [9]. More specifically, from patients' point of view, they more focus on tangibility and assurance. However, in regards to adopting health information technologies, patients will concentrate on convenience and interaction rather than tangibility. Therefore, *via* enhancing the convenience and patients' service perception, health information technologies may facilitate improving hospital service quality to a large extent. From interaction perspective, it emphasis on responsiveness and empathy. On the other hand, convenience refers to a hospital deliveries high standard service to scale patients' demands *via* hardware and software supports, for instance, patients' waiting time reduction, information inquiry easiness, payment convenience etc. Although, it is considered that convenience is more tangible based, it is not identical in this context. In particular, different authors may hold different views of convenience, such as convenience itself [10-12], patient flows [13] or waiting time [14,15]. Thus, convenience can be determined by patient clinic waiting time and clinical information accessibility. As a result, it can be suggested that convenience should be included in SERVQUAL or service quality dimensions, especially when considering patients' using health information technologies to get efficient and extensive clinical process.

Dimensions and Factors Associated with Service Quality

In early 1990's, service quality has been well defined and illustrated in many researches. Garvin [16] defined the key dimensions of service quality as serviceability, aesthetics, and perceived quality in the user based definition approach. In common scenarios, service quality could only be evaluated and measured during the interaction process between customer and service suppliers rather than before the interaction or as the interaction results neither [17,18]. Meanwhile, Gronroos [19] divided service qualities in two types: technical quality (i.e. what service is delivered) and functional quality (how the service is delivered). Furthermore, Parasuraman, Zeithaml and Berry [20] established the most influential concept model of SERVQUAL. It, as an analytic hierarchy, measures the service quality process and delivery against customers' expectations and experience in ten dimensions, which had been modified to five dimensions *via* research advancement process [21]. These five dimensions are tangibility, reliability, responsiveness, assurance, and empathy. This developed conceptual model is widely used in further study explorations among various service industries.

Based on the original five dimensions of SERVQUAL, Babakus and Mangold [22] modified the SERVQUAL particularly adopt-

ed by healthcare sector. As a result, the revised model has been broadly adopted to investigate on patient perceived healthcare service quality [22]. With the emerging of published researches on SERVQUAL and the healthcare service quality [23-26], the two main streams of study has been formed which are dimensions of the services quality and the application of SERVQUAL to evaluate hospital service quality. Additionally, researchers assessed the quality of Iranian healthcare services that adopt SERVQUAL tool *via* meta-analysis, and expected to investigate the association between demographic information and SERVQUAL [26]. Pai and Chary [23] explored the diversity of SERVQUAL dimensions and methodology to develop structure. Meanwhile, Fatima [24] illustrated many sub-dimensions in accordance with service quality and proved that SERVQUAL is constantly the most common used conceptual model to evaluate the health service quality. Additionally, Talib, Azam and Rahman [27] combined the research on the service quality and the patients' satisfaction.

METHODOLOGY

The Main Hypothesis

To establish and hypothesize the research framework for this study, we examined the relationships between variables of the MHAU and service quality in existing literature. Chang and Chang [28] used the term "technology based service encounters" to describe the interaction between medical practitioners and patients during clinical process by e-commerce and Internet technology, such as online appointment system (OAS) and EHRs, revealing positive effect of technology based service encounters service quality without effecting patient satisfaction. Perception of service quality has a positive impact on patient satisfaction *via* the adoption of technology based service. While in a study of effect of OAS on patient satisfaction, Wang, Cheng and Huang [29] claimed that OAS technology based service encounters, compared with the hospital image, had a stronger effect on patient satisfaction. Based on the above results, we hypothesize that:

H1a: MHAU has a positive effect on patient's perception of service quality.

H1b: MHAU has a positive effect on patient satisfaction.

Technology acceptance has a significant effect on relationship quality which is defined as the outcome of interactions between both parties [30,31]. Wu, Li and Li [32] applied the construction of "interaction quality" to describe how the service is delivered. It can be explained as the patient's cognition of service quality in communication with doctors and nurses. Generally, it claimed that interactive quality has a positive effect on overall experience quality [33]. In addition, Petter and Fruhling [34] indicated that the system usage, as a variable to measure use of STAT Pack™ (an information tool used to aid in the diagnosis of pathogens in hospitals), has positive effect on individual and organization. These two variables describe how effective and useful the individual and organization using STAT Pack™. The results suggest that the use of the technology or systems may result in the change of the interaction between patients and doctors, thereby affecting perceived service quality. Thus, in our study, we hypothesized that the way of the

MHAU affecting the patient perceived service quality works by the mediating role of clinical process change perceived by patient. Consequently, based on the discussion above, we can draw a conclusion and put forward hypotheses as follows:

H1c: MHAU is positively push forward clinical process change perceived by patients.

H2: Clinical process change perceived by patients has positive effect on perceived service quality in hospitals.

In the investigation of relationship between service quality and patient satisfaction, some authors state that service quality directly effects on patient satisfaction [35-41], while others argue that service quality influences the patient satisfaction by mediating factors [42-45]. Faria and Mendes [46] confirmed that apart from the direct effect of service quality on patient satisfaction, the institutional reputation also fluctuate the relationship between service quality and patient satisfaction. Johnson and Russell [47] found the mediating role of healthcare provider and nurse/assistant within service quality and patient satisfaction. Thus, we hypothesize that:

H3: The perceived service quality is positively related to patient satisfaction.

Control Variable

To make the study more scientific, we identified four control variables: gender, age, education, and occupation. Usually, compared with the women, men is more rational and insensitive and more likely to satisfaction, they tend to simplify complex problems when they experience trouble. Compared with the older, the younger show skilled use in health information technologies, while the older tend to show fear for using these technologies, which can easily trigger dissatisfaction among older patients. The level of education is usually proportional with the ability to solve and identify problems, with the ability to proficient use in health information technologies. Patients' occupation is significantly associated with skilled use of health information technology. Based on this, the gender, age, education, and occupation of the respondents were included as control variables that might influence patient satisfaction.

Research Model

Based on the above hypotheses, the research model was established, as illustrated in **Figure 1**.
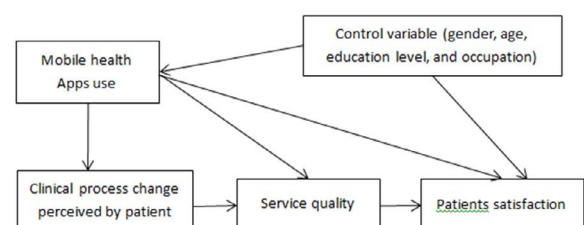

Figure 1: Research model and hypotheses formulated in this study

RESEARCH DESIGN

Questionnaire Design

By reviewing a large amount of literature, we directly intro-

duced, selected, and modified the relevant mature scale to design variables and items of this study. The total number of scales is four, with eleven dimensions, which are: MHAU, clinical process change perceived by patient (dimensions included: physician-patient interaction, and information accessibility), service quality (dimensions included: tangibility, reliability, responsiveness, assurance, empathy, and convenience) and patient satisfaction (dimensions included: treatment outcome and visit time) with measurement of control variables, some demographic variables may have an impact on patient performance. Each questions of the scale and its' source reference

Table 1. Furthermore, the independent variable, MHAU, may be affected by the patient's gender, age, education level, and occupation, thus indirectly or directly affecting the patient satisfaction. In addition, the above control variable may also have effects on the patient perceived clinical process change and service quality. Therefore, the gender, age, education, and occupation of the respondents were added to the measurement scale. The Likert 7-point recording method was adopted for each item, with 1 being "very disagree" and 7 being "very agree" [48].

Table 1: Source of the questions of each scale

Variable		Number	Items	Source
Mobile Health Apps Use (MHAU)		a	Make an appointment for doctor	[47]
		b	Pay for medical related expenses	[39,43,45,52]
		c	Check laboratory reports and medical records	
		d	Interact with the doctor you want to consult online at any time	
		e	Communicate with other patients	[43,52]
		f	Ask medical staff questions *via* SMS	
		g	Learn about health education information and medical information pushed by hospitals	
Clinical Process Change perceived by patient	Physician-patient Interaction	a	Now I can make an appointment to the doctor who I want to see every time	[45]
		b	When I choose a doctor, I can get information about the doctor's background and experience online	
		c	When I choose a doctor, I can see other patients' scores and assessments on the Internet	
		d	After seeing the doctors, I can rate the doctor online.	
		k	Now I can manage and treat my disease more effectively	[43,52]
		l	Now I can keep in touch with other patients online	
		m	I can now ask the medical staff questions *via* SMS on the Internet	
		n	Every link in my medical treatment process is now more coherent	
		o	I am maintaining a continuous communication relationship with my doctor	
		cc	Now the queue has been reduced in every link of my medical treatment	[47]
		dd	I took the initiative to participate in discussions with doctors about treatment options	[45-46]
		ee	I actively seek other information related to my health	
		ff	I take the initiative to participate in learning preventive treatment information	
		gg	After I see a doctor, I will take the initiative to follow up and complete all the required treatments	
		hh	I took the initiative to help the doctor determine my health and problems	
		ii	The medical staff in the hospital now know the records of every link of my visit very well	
		jj	In every aspect of my medical treatment process, the data related to me can be checked in time	
		kk	In every aspect of my medical treatment, medical staff are now in harmony with each other	[43,52]
		ll	It's easy for me and the medical staff to make a common agreement now	
	Information Accessibility	e	I can easily access and store my medical information now	
		f	I can now access and process my medical information anytime and anywhere	
		g	Now, when I am in the hospital, the medical staff in different departments are well coordinated with each other	

		h	Now even if I am looking for a different doctor in the hospital, the process of diagnosis and treatment is consistently standardized	
		i	I can now check the medical records of the past at each stage of the hospital	[35]
		j	Now if the medical staff I'm looking for is not there, other medical staff can meet my needs	[40]
		p	Now the doctor can give me the most suitable treatment according to my personal condition and complete historical information	[35]
		q	Now my doctor's treatment plan is consistent with my changing needs and conditions	[46]
		r	Now that I'm in the hospital, I know exactly who I'm looking for at every step	[46]
		s	The doctor encouraged me to ask questions	[42,52]
		t	The doctor will answer my questions adequately	
		u	The doctor actively encouraged me to participate in discussions with the doctor about treatment options	
		v	Doctors offer other information about my condition and treatment on their own initiative	[40]
		w	Doctors actively provide information on preventive treatment	[42,52]
		x	I can understand the explanation given by the doctor	[43,45,52]
		y	The doctor was very considerate of me	
		z	The doctor made me feel at ease discussing my condition	
		aa	I feel that the doctor knows my medical history very well	[55]
		bb	I feel that doctors know very well about my health care needs	
Service quality	Tangibility	a	The hospital is clean	
		b	The hospital's medical equipment is very advanced	[50]
		c	Doctors and nurses dress professionally and neatly	
		d	The signs of hospital facilities are very clear	
		e	The TV screen in the waiting area shows useful information for the patient	[55]
		f	In many places in the hospital, you can see promotional materials that guide how to use the hospital WeChat application	
	Reliability	g	My doctor is very concerned about my personal situation	[50]
		h	My doctor is based on my special condition	[56]
		i	My doctor understands my specific needs	[55]
		j	My doctor is concerned about my unique needs	[50]
		k	My doctor showed great sympathy for my condition	[56]
	Assurance	l	My doctor has the ability to treat me well	[50]
		m	When the doctor came to see me, I felt safe	
		n	The way and behavior of my doctor give me great confidence	
		o	My doctor has good medical knowledge	
		p	My doctor is trustworthy	[55]
		q	My doctor is very experienced	[36]
	Convenience	r	I can easily make an appointment with the doctor I want to see	[45]
		s	I can easily make an appointment to the time I want to see a doctor	
		t	It's easy for me to find where I need to go in the hospital	
		u	I don't have to wait long in hospital	[47]
		v	Every step of seeing a doctor in my hospital is very convenient and easy	[45]
		w	The hospital staff will always help me whenever I need	[50]
	Reliability	x	My doctor seldom makes mistakes	
		y	My doctor always explains the diagnosis and treatment to me very clearly	
		z	My medical record in the hospital is always accurate	[55]
		aa	There are few inconsistencies in my medical records	[50]
		bb	The service of medical staff is always reliable	
	Responsiveness	cc	My doctor can answer my question quickly	[54]
		dd	I always get prompt answers when I contact the hospital	

		ee	Doctors and nurses are not too busy to answer my questions in time	
		ff	My doctor will keep updated of my condition changes	
		gg	My doctor will make quick adjustments to my condition	
Patient Satisfaction	Treatment Outcome	a	I am satisfied with the medical services I received during my stay in this hospital	
		b	I'm very satisfied with the doctor's attitude	[42,44]
		c	I am very satisfied with the quality of the doctor's treatment	
		d	My illness has been properly treated	
		e	After seeing the doctor, I have a better understanding of my condition	[43,52]
		f	After talking with the doctor, I feel a lot better about my condition	
		g	The doctor's choice of treatment is the most appropriate for me	
		h	My condition will be completely improved	
		l	I'm satisfied with the doctor's consultation time	
		m	I am satisfied with the waiting time in the hospital	
		n	I'm satisfied with the total time spent on this visit	
	Visit Time	i	I'm very clear about how to recover when I get home	
		j	I am very clear about how to use the medicine	[46-47]
		k	I know exactly when to see the doctor next time.	

Data Collection

In order to improve the validity of the questionnaire as much as possible, the paper version of the questionnaire was adopted. The patients were required to fill out the questionnaires as long as the medical consultation was approaching to the end on the paperwork. From December 19, 2018 to January 22, 2019, 647 questionnaires were issued, which involved 618 valid questionnaires. The rate of sample validity was 95.5%. The reasons for the invalid questionnaires are: the patients were impatient to answer questions which lead to the filling time is significantly lower than the rational and reasonable filling time of 20 minutes; the patients were very concentrating at the beginning, but they were interrupted by some emergency issue; some critical questions were neglected.

EMPIRICAL TEST AND RESULT ANALYSIS

Demographic Analysis

The demographic information of patients who use mobile health apps is summarized in Table 2. The proportion of patient gender was 39% (male) and 61% (female), respectively. The majority of patients' age were between 31 and 40, accounting for 46.3% of the total patients interviewed, followed by those ages between 21-30 and 11-20, accounting for 27% and 10.2%, showing that the group of patients using mobile health technologies were younger generation, and basically matched with the age distribution of overall patients in the hospital. The ratio of the patients who have the bachelor degree and diploma was the largest, accounting for 41% and 21.4% of the total, indicating that the education level of the targeted patients was generally high. From the perspective of occupation, the highest proportion was non-government related enterprises, such as foreign-funded enterprises, privately owned corporations and self-employed households, accounting for 59.5%. In summary, the distribution of the demographic information of the patient samples in this study is even and reasonable and can represent the overall patient population of the hospital.

Table 2: Summary of the demographic information of patients (N=618)

Variable	Category Description	Sample size	Ratio (%)
Gender	M	241	39
	F	377	61
Age	10 and under	19	3.1
	11~20	63	10.2
	21~30	167	27
	31~40	286	46.3
	41~50	51	8.3
	51~60	20	3.2
	61 and above	12	1.9
Occupation	Government	11	1.8
	Government-affiliated Institutions	49	8
	State-owned Enterprises	44	7.1
	Private-owned Company	149	24.2
	Foreign Enterprises	54	8.8
	Private Enterprises	64	10.4
	Self-employed Households	99	16.1
	Farmers	30	4.9
	Students	62	10.1
	Others: Retirement, Unemployment, Full-time mother	54	8.9
Education	Doctor	5	0.8
	Master	35	5.7
	Bachelor	253	41
	Diploma	132	21.4

Vocational Technical School	37	6
High School	73	11.8
Junior Middle School	52	8.4
Primary School	28	4.5
Kinder garden	2	0.4

Measurement Reliability

We conducted the reliability test using Cronbach's α-coefficient in this study. The α-coefficient is usually expected to be greater than 0.7, indicating that the reliability is acceptable [48]. To determine the factors that affect the reliability, we may calculate the corrected item total correlation (CITC) value. If the CITC is lower than 0.4 or the α-coefficient increases after deletion, we could consider deleting the corresponding question. Reliability analysis requires a separate analysis for each variable. The α-coefficients of the each variables or dimensions is greater than 0.7 (**Table 3**), indicated that the reliability of each variable is acceptable. The Cronbach's coefficient of the subscale is higher than 0.8 (**Table 3**), and the Cronbach's coefficient of the total scale is 0.846 (**Table 3**), indicating that it is relatively reliable.

Table 3: Reliability analysis of variables and dimensions

Variables	Dimensions	Cronbach's α
Mobile health apps use (MHAU)		0.839
Clinical process change perceived by patient	Information Accessibility (IA)	0.848
α=0.822	Physician-patient Interaction (PI)	0.713
Patient satisfaction	Treatment Outcome (TO)	0.861
α=0.845	Visit Time (VT)	0.93
Service quality	Tangibility (Ta)	0.872
α=0.861	Empathy (Em)	0.886
	Assurance (Ass)	0.857
	Convenience (Co)	0.815
	Reliability (Rel)	0.848
	Responsiveness (Res)	0.796
Total scale		0.846

The results showed that the reliability of each variable and dimension was very high, and the CITC values of all the questions were greater than 0.4 and deleting any one of the questions did not improve the overall α-coefficient. Therefore, those 11 variables (including all dimensions), as well as 41 question items do not need to be modified or deleted, and its results are reliable.

Measurement Validity

The validity test included content validity and construct validity in this study. The content validity of the scale adopts the mature scale content, and is supported by a lot of theories. Meanwhile, five hospital management experts were invited to examine the content of the scale to ensure the content validity. The items used in this study mainly refer to the scales used by previous researchers, as well as the experience and opinions of experts, after revision, the contents completely conform to the conceptual description of relevant variables.

SPSS 24 statistical software was used for the exploratory factor analysis to verify the validity of the questionnaire structure in this study. Before exploratory factor analysis, KMO (Kaiser-Meyer-Olkin) statistics and Bartlett sphere test were used to determine whether the data were applicable for the factor analysis. If the KMO value is greater than 0.6, which is the general standard, and the p value of Bartlett spherical test is 0.000, less than 0.01, it indicates that the statistics is applicable for the factor analysis. Results of the structural validity analysis of MHAU, clinical process change perceived by patient (physician-patient interaction and information accessibility), service quality (tangibility, reliability, responsiveness, assurance, empathy, and convenience) and patient satisfaction (treatment outcome and visit time) are shown in **Tables 4-7**. Results of the factor analysis demonstrated that the co-relationship between the four variables and each factor basically met the professional requirements. The factor loading coefficient is all higher than 0.6, indicating that the structural validity of the questionnaire is attainable, and the data is valid.

Table 4: Construct validity analysis of mobile health apps use (MHAU)a

No.	Items	Factor
		1
2a	Make an appointment for doctor	0.638
2b	Pay for medical related expenses	0.72
2c	Check laboratory reports and medical records	0.796
2d	Interact with the doctor you want to consult online at any time	0.822
2e	Communicate with other patients	0.767
2g	Learn about health education information and medical information pushed by hospitals	0.715
Eigenvalue		3.335
Cumulative Variance Interpretation Rate		55.584
KMO		0.793
Bartlett's Test of Sphericity		1658.439
Sig		0

Extraction Method: Principal Component Analysis, a:1 component extracted.

Table 5: Construct validity analysis of clinical process change perceived by patient a

No.	Items	Factor	Construct
		1	2
3f	Now I can keep in touch with other patients online	0.817	
3g	I can now ask the medical staff questions *via* SMS on the Internet	0.844	
3t	I can easily access and store my medical information now	0.807	
3u	I can now access and process my medical information anytime and anywhere	0.8	

No.	Items	Factor 1	Factor 2
3a	Now I can make an appointment to the doctor who I want to see every time	0.635	
3l	I actively seek other information related to my health	0.647	
3dd	The doctor will answer my questions adequately	0.817	
3ff	Doctors offer other information about my condition and treatment on their own initiative	0.783	
Rotated Eigenvalue		2.76	2.25
Rotated Variance Interpretation Rate		34.501	34.501
Cumulative Variance Interpretation Rate		28.123	62.623
KMO			
Bartlett's Test of Sphericity		2224.485	
Sig		0	

Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalizion, a: Rotation converged in 3 iterations.

Table 6: Construct validity analysis of patient satisfactiona

No.	Items	Factor	Construct
		1	2
4b	I'm very satisfied with the doctor's attitude	0.837	
4c	I am very satisfied with the quality of the doctor's treatment	0.815	
4d	My illness has been properly treated	0.842	
4f	After talking with the doctor, I feel a lot better about my condition	0.807	
4j	I am satisfied with the waiting time in the hospital		0.95
4k	I'm satisfied with the total time spent on this visit		0.95
Rotated Eigenvalue		2.785	1.92
Rotated Variance Interpretation Rate		46.409	32.008
Cumulative Variance Interpretation Rate		46.409	78.417
KMO		0.739	
Bartlett's Test of Sphericity		2128.748	
Sig		0	

Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalizion, a: Rotation converged in 3 iterations.

Correlation Analysis

Correlation analysis was conducted on the four variables and their dimensions, and all relevant results were summarized in **Table 8**. The correlation analysis showed that MHAU had the strongest correlation with information accessibility at the dimension level (correlation coefficient=0.813, p<0.01). Except for the moderate correlation with visit time (correlation coefficient=0.401, p<0.01), the other factors were weak or no correlation. Apart from the strong correlation with MHAU, information accessibility was invisible or irrelevant to all other dimensions. There was a low correlation between physician-patient interaction and tangibility (correlation coefficient=0.368, p<0.01), and there was a moderate correlation between physician-patient interaction and other five dimensions of service quality. There was a weak correlation between the six dimensions of service quality and visit time. The most relevant element was convenience (correlation coefficient=0.396, p<0.01), while the six dimensions of service quality and treatment outcome were all moderately correlated.

Regression Analysis and Validation of Model Hypothesis

Multiple linear regression analysis was used to verify the relationship between independent variables and dependent variables in this study. For the purpose of preventing the interference caused by the sample demographic information, the study included the patient's age, gender, occupation and education level those were used as control variables in the model for analysis. The analysis of the relationship between model variables is conducted at two levels. The first level is among four variables, and the second level is between the dimensions of variables. Therefore, we established three groups of independent variables and dependent variables during the regression analysis. They are:

Group 1: Independent variables: MHAU; dependent variables: clinical process change perceived by patient (physician-patient interaction and information accessibility).

Group 2: Independent variables: MHAU, clinical process change perceived by patient (physician-patient interaction and

information accessibility); dependent variables: service quality (tangibility, empathy, assurance, convenience, reliability and responsiveness).

Group 3: Independent variables: MHAU, service quality (tangibility, empathy, assurance, convenience, reliability and responsiveness); dependent variables: patient satisfaction (treatment outcome and visit time).

Table 7: Construct validity analysis of service quality a

No.	Items	Factor					
		1	2	3	4	5	6
5a2	The hospital is clean	0.784					
5b2	The hospital's medical equipment is very advanced	0.814					
5c2	Doctors and nurses dress professionally and neatly	0.799					
5d2	The signs of hospital facilities are very clear	0.755					
5g2	My doctor is very concerned about my personal situation		0.755				
5h2	My doctor is based on my special condition		0.73				
5i2	My doctor understands my specific needs		0.723				
5j2	My doctor is concerned about my unique needs		0.765				
5o2	My doctor has good medical knowledge				0.665		
5p2	My doctor is trustworthy				0.73		
5q2	My doctor is very experienced				0.768		
5r2	I can easily make an appointment with the doctor I want to see					0.812	
5s2	I can easily make an appointment to the time I want to see a doctor					0.834	
5u2	I don't have to wait long in hospital					0.602	
5z2	My medical record in the hospital is always accurate						0.709
5aa2	There are few inconsistencies in my medical records						0.754
5bb2	The service of medical staff is always reliable						0.618
5dd2	I always get prompt answers when I contact the hospital			0.6			
5ee2	Doctors and nurses are not too busy to answer my questions in time			0.787			
5ff2	My doctor will keep updated of my condition changes			0.773			
5gg2	My doctor will make quick adjustments to my condition			0.651			
Rotated Eigenvalue		3.187	3.011	2.623	2.292	2.256	2.125
Rotated Variance Interpretation Rate		15.177	14.34	12.491	10.912	10.744	10.121
Cumulative Variance Interpretation Rate		15.177	29.517	42.008	52.92	63.665	73.785
KMO		0.943					
Bartlett's Test of Sphericity		7726.062					
Sig		0					

Extraction Method: Principal Component, Analysis Rotation Method: Varimax with Kaiser Normalizion, a: Rotation converged in 6 iterations.

Table 8: Correlation analysis of dimensions in research model

Dimensions	MHAU	IA	PI	Ta	Em	Ass	Co	Rel	Res	TO	VT
MHAU	1										
IA	.813**	1									

PI	.327**	.376**	1								
Ta	.288**	.284**	.368**	1							
Em	.264**	.259**	.481**	.523**	1						
Ass	.205**	.220**	.434**	.600**	.605**	1					
Co	.230**	.199**	.497**	.399**	.575**	.487**	1				
Rel	.281**	.288**	.510**	.539**	.651**	.665**	.573**	1			
Res	.185**	.194**	.424**	.404**	.589**	.514**	.532**	.602**	1		
TO	.324**	.364**	.582**	.541**	.573**	.579**	.438**	.588**	.465**	1	
VT	.401**	.398**	.331**	.326**	.378**	.237**	.396**	.360**	.317**	.358**	1

**. Correlation is significant at the 0.01 level (2-tailed)

Note: MHAU=mobile healthy applications use; IA=information accessibility; PI=physician-patient interaction; Ta=tangibility; Em=empathy; Ass=assurance; Co=convenience; Rel=reliability; Res=responsiveness; TO=treatment outcome; VT=visit time

The results of the three groups at variables and dimensions level are shown in **Tables 9**.

In the regression analysis of clinical process change perceived by patient and its dimensions as dependent variable, MHAU had a positive effect on clinical process change perceived by patient (regression coefficient=0.456, p<0.01) while the other

Table 9: Regression analysis of clinical process change perceived by patient and its dimensions as dependent variable

Dependent variable	Independent variable	Unstandardized		Standardized Coefficients	t	Sig.	R^2	Adjusted R^2	F
		B	Std. Error	Beta					
CPC perceived by patient and its dimensions as dependent variable	CPC	MHAU	0.456	0.026	0.619	17.549	0	0.404	0.384	20.008**
	IA	MHAU	0.717	0.037	0.66	19.436	0	0.447	0.428	23.810**
	PI	MHAU	0.196	0.029	0.284	6.693	0	0.138	0.109	4.719**
SQ and its dimensions as dependent variable	SQ	MHAU	-0.011	0.025	-0.021	-0.434	0.665	0.272	0.246	10.392**
		CPC	0.316	0.033	0.471	9.533	0			
	SQ	MHAU	0.044	0.024	0.089	1.809	0.071	0.349	0.325	14.110**
		IA	0.032	0.023	0.069	1.391	0.165			
		PI	0.342	0.029	0.477	11.961	0			
	Ta	MHAU	0.093	0.035	0.149	2.688	0.007	0.169	0.137	5.330**
		IA	0.047	0.032	0.081	1.445	0.149			
		PI	0.212	0.041	0.236	5.219	0			
	Em	MHAU	0.029	0.037	0.04	0.766	0.444	0.254	0.225	8.925**
		IA	0.065	0.035	0.099	1.853	0.064			
		PI	0.399	0.044	0.388	9.08	0			
	As	MHAU	0.019	0.033	0.031	0.581	0.562	0.219	0.19	7.380**
		IA	0.035	0.031	0.062	1.128	0.26			
		PI	0.331	0.039	0.369	8.437	0			
	Co	MHAU	0.068	0.042	0.083	1.599	0.111	0.267	0.239	9.554**
		IA	-0.031	0.04	-0.041	-0.775	0.439			

		PI	0.52	0.05	0.441	10.415	0			
	Rel	MHAU	0.048	0.034	0.073	1.407	0.16	0.282	0.255	10.308**
		IA	0.065	0.032	0.105	2.008	0.045			
		PI	0.409	0.041	0.423	10.077	0			
	Res	MHAU	0.008	0.023	0.018	0.328	0.743	0.207	0.177	6.856**
		IA	0.003	0.022	0.007	0.127	0.899			
		PI	0.24	0.027	0.389	8.819	0			
PS and its dimensions as dependent variable	PS	MHAU	0.162	0.022	0.246	7.479	0	0.521	0.504	30.201**
		SQ	0.784	0.044	0.589	17.651	0			
	PS	MHAU	0.156	0.022	0.236	7.062	0	0.525	0.503	23.780**
		Ta	0.185	0.042	0.175	4.379	0			
		Em	0.192	0.043	0.207	4.477	0			
		Ass	0.068	0.049	0.064	1.382	0.168			
		Co	0.12	0.033	0.148	3.635	0			
		Rel	0.133	0.048	0.135	2.745	0.006			
		Res	0.042	0.067	0.027	0.621	0.535			
	TO	MHAU	0.075	0.022	0.119	3.472	0.001	0.499	0.475	21.395**
		Ta	0.175	0.041	0.173	4.216	0			
		Em	0.174	0.042	0.196	4.127	0			
		Ass	0.233	0.048	0.23	4.828	0			
		Co	0.012	0.032	0.015	0.365	0.715			
		Rel	0.143	0.048	0.152	3.004	0.003			
		Res	0.033	0.066	0.022	0.496	0.62			
	VT	MHAU	0.317	0.047	0.274	6.719	0	0.297	0.264	9.087**
		Ta	0.205	0.09	0.11	2.271	0.024			
		Em	0.228	0.092	0.14	2.491	0.013			
		Ass	-0.262	0.105	-0.14	-2.495	0.013			
		Co	0.336	0.071	0.236	4.764	0			
		Rel	0.113	0.104	0.065	1.091	0.276			
		Res	0.06	0.144	0.022	0.416	0.678			

$^{*}P<0.05$, $^{**}P<0.01$

Note: MHAU=mobile healthy applications use; IA=information accessibility; PI=physician-patient interaction; Ta=tangibility; Em=empathy; Ass=assurance; Co=convenience; Rel=reliability; Res=responsiveness; TO=treatment outcome; VT=visit time; SQ=service quality; PS=patient satisfaction; CPC=clinical process change.

variables had no effect. Therefore, H1c should be accepted. In the regression analysis of the two dimensions of clinical process change perceived by patient, it was found that MHAU had a significant positive effect on both information accessibility (regression coefficient=0.717, p<0.01) and physician-patient interaction (regression coefficient=0.196, p<0.01).

In the regression analysis of service quality and its dimensions as dependent variable, it was found that the impact of MHAU on service quality is insignificant (P=0.665>0.05), nevertheless, it had a positive effect on tangibility exclusively (regression co-efficient=0.093, p=0.007<0.01). While physician-patient interaction had an extensive positive effect on the six dimensions of service quality, and information accessibility had a positive effect only on the reliability of service quality (regression coefficient=0.065, P=0.045<0.05). Thus, the null H1a is rejected unverifiable and alternative H2 is accepted.

In the regression analysis of patient satisfaction and its dimensions as dependent variable, the regression coefficients of MHAU and service quality as independent variables were 0.162 and 0.784, respectively. The p=0.01 confidence level was sig-

nificant, indicating that the above two variables could impact patient satisfaction positively. Therefore, the H1b and H3 will be accepted.

In the study of the influence of various dimensions of service quality on patient satisfaction, we found that tangibility (regression coefficient=0.185, P=0.000<0.01), empathy (regression coefficient=0.192, p=0.000<0.01), convenience (regression coefficient=0.120, p=0.000<0.01), reliability (regression coefficient=0.133, p=0.006<0.01), have positive effect on patient satisfaction, while the influence of assurance (regression coefficient=0.068, p=0.168>0.01) and responsiveness (regression coefficient=0.042, p=0.535>0.01) is null.

In the study of the influence of MHAU and the dimensions of service quality on the treatment outcome and visit time, it is found that MHAU, tangibility and empathy had significant positive effect on the treatment results and the treatment time; assurance and reliability only had a positive effect on the treatment outcome, but have no significant effect on visit time; convenience only had a significant effect on visit time, while there was no effect on treatment outcome; responsiveness had no effect on both treatment outcome and visit time.

DISCUSSION

Empirical Finding

The study found that the MHAU had no impact on perceived service quality but has a positive effect on its tangible dimension, patient satisfaction and both of its two dimensions. This result is consistent with the contemporary studies on the impact of technology based physician-patient service contact on patient satisfaction, as well as the research on the use of mobile information communication devices on patient satisfaction [29,49]. In this research it is demonstrated that the MHAU has a positive effect on patient satisfaction but has no effect on perceived service quality as a result of the conceptual differences in satisfaction and service quality. Satisfaction is the overall evaluation of the hospital's service through the actual experience. This feeling is temporary and immediate. The perception of service quality is the patient's understanding of the hospital service content. The understanding is constant, not necessarily access through personal experience. Experiences, such as patients who think that the professional level of a doctor in a hospital or the overall service quality of a hospital is high, can be obtained through notification or publicity of others, advanced equipment technology (both medical devices and digital clinical process) or architecturally well designed hospitals. This further illustrated that the medical software, which is a tangible factor of service quality, has a positive effect. To explain more profoundly, the use of health information technologies belongs to the patient's personal experience, and the perception it generates could be more closely related with satisfaction than the quality of service. This can also be confirmed by the correlation analysis results.

The study also found that the MHAU has a positive effect on clinical process change perceived by patient and its two dimensions, which is corresponded to the results of Petter and Fruhling [34] in studying the changes in clinical processes perceived by patients after using the STAT Pack™ system to help diagnose pathogens in hospitals. However, only physician-patient interaction has a significant positive effect on service quality and its dimensions, which is consistent with Wu, Li and Li [32] finding that is physician-patient interaction has a positive effect on patient service quality. In addition, since the MHAU has no effect on the quality of service, this indicates that the change in the patient's experience in the clinical process is an intermediate variable affecting the quality of service by MHAU. That is, the use of health information technologies initially changes the patient's experience in the clinical process, then the patient's perception of quality of hospital service, and the investment of health information technologies itself will not lead to an increase in perception of service quality. This view could explain why adoption of the EHRs in the ophthalmological hospitals did not enhance the efficiency of workflow [7], because due to the lack of meaningful interaction between physicians and patients [6], which gave rise to the undesirable patient experience despite how much of health information technologies that hospitals explored. In addition, the study confirms that service quality has a positive effect on patient satisfaction, which is consistent with the results of many researchers [50-56].

Theoretical Contribution

From the theoretical point of view, firstly, in terms of poor medical environment in Chinese hospitals, it is proposed that patients use health information technologies to influence the quality of service through the perceived changes of clinical process as an intermediate variable, which has never been reported in previous literature. Secondly, the study proposes to facilitate convenience to the dimension of hospital service quality, which has been verified and supplemented the original five dimensions of SERVQUAL scale.

Practical Significance

From the practical perspective, firstly, when hospital initiates to invest in new equipment or system, they should not only focus on the introduction of system use, but also, more importantly, the changes of patients' experience in the clinical process after using systems or apps. Especially, the perception of change in initiatives of physician-patient interaction concerns patients are one of the most influential factors. Therefore, hospitals may choose to establish a better way to promote user interface friendly systems for both medical staff and patients by easily sharing messages, pictures, videos and other medical information. This point of view is also confirmed in the study that the negative perception of EHRs (i.e. electronic health records) productivity outcomes in the ophthalmological hospital can be improved by optimizing the usability of systems [6]. Secondly, in regards to hospitals with large outpatient visits in China, the evaluation of hospital service quality should be considered for convenience added in to the five dimensions commonly used for SERVQUAL. In this study, it is found that hospitals with larger patient's populations and patients in larger hospitals are more concerned about convenience. Two hospitals mentioned in literature have a capacity of 880 and 600 beds, which can be considered as large hospitals [57,58]. The patients consider convenience as the primary factor affecting service quality. Specifically, prominent hospitals always bear excessive amount of patients' population, which leads to the inefficient clinic pro-

cess and poor service quality. As the research object, Shenzhen Ophthalmology Hospital is a public hospital in Shenzhen, China, which obtained more patients gathering for clinical treatment, with over 400,000 outpatient volume. During the investigation, patients in Shenzhen Ophthalmology Hospital concern more about the convenience in their entire clinical procedure. Therefore, in this context, convenience may be dimensions that have a greater effect on service quality perception.

Limitations and Future Research Directions

This study obviously has some limitations that could be improved in the further research in terms of model establishment, sample selection and research methods. The research model mainly explores the influence mechanism of MHAU on patient satisfaction but does not consider the relevant factors that affect the use of MHAs, such as the patient's ability to acquire knowledge and technology, social influencing factors, and perceived features of mobile technology. Additionally, the research object is only one public hospital included, SOH, so the representativeness and comprehensiveness of the research results could be improved by involving other general hospitals to conduct comparative studies between public and private hospitals or by considering comparative studies of similar hospitals in different regions (**Supplementary file**).

CONCLUSION

In regards to this study, the MHAU directly and significantly affects patient satisfaction, but it has no direct effect on the hospital service quality. Nevertheless, it affects the variable of perceived changes of clinical process by patients at first, then the hospital service quality. Physician-patient interaction is an important factor that positively affects the quality of hospital service. Convenience is one of the important dimensions for patients to perceive the quality of service in Chinese hospitals, and it has a positive and significant effect on patient satisfaction. Furthermore, hospital management level should not only concentrate on the management system usage, but also on the organizational factors that affect the results of system usage, such as the perceived clinical process change by patients. When evaluating the quality of hospital service, especially in terms of large scale hospitals with large outpatient service range, the convenience dimension should be considered. Furthermore, managers should focus on enhancing the initiative of physician-patient interaction, as it is an important factor affecting patients' perception of hospital service quality. Generally, this study provides evidence that can be referred in other investigations in a similar context and also need to be confirmed by future researchers in other hospital settings.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the School of Medical Technology and Nursing (Shenzhen) research ethics committee. As a questionnaire survey was conducted in the study that informed consent was obtained from all interviewees in the manuscript. All methods were carried out in accordance with relevant guidelines and regulations in the ethical approval and consent to participate section of manuscript.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY STATEMENT OF DATA AND MATERIAL

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

COMPETING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

AUTHORS' CONTRIBUTIONS

CJ and CW wrote the study design and the manuscript. CJ conducted literature review and CJ and CW analyzed the data of literature and wrote the paper, LZ and KZ refined the research design, revised, reviewed manuscript and made final editing, XZ was responsible for language correction and revision, and participated in the data analysis, and all authors agreed with the manuscript's results and conclusions.

ACKNOWLEDGEMENTS

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