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Predictors of Dental Students' Behavioral Intention Use of Teledentistry: An Application of the Unified Theory of Acceptance and Use of Technology (UTAUT) Model

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PREDICTORS OF DENTAL STUDENTS' BEHAVIORAL INTENTION USE OF TELEDENTISTRY: AN APPLICATION OF THE UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT) MODEL

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ABSTRACT

PREDICTORS OF DENTAL STUDENTS' BEHAVIORAL INTENTION USE OF TELEDENTISTRY: AN APPLICATION OF THE UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT) MODEL

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Shortages of dental professionals and access barriers to dental care are challenges to improving oral health and decreasing the burden of dental diseases. There are more than 57 million individuals in the U.S. who live in dental health professional shortage areas (DHPSA). The U.S. DHPSA areas need 9,951 dental practitioners to overcome the obstacles to oral care access. Due to dental care needs for these populations, it is imperative to find a new method to reach these underserved populations. Teledentistry is an innovative technology that can be used to improve access to care and oral health outcomes. Unfortunately, there is still limited utilization of teledentistry in dental practice in the U.S. Many studies have investigated factors associated with the applications of telehealth and telemedicine; however, limited investigations have addressed the barriers to the use and implementation of teledentistry.

The overarching purpose of this dissertation was to explore factors associated with the future use of teledentistry among predoctoral dental students. To achieve this purpose, three interrelated projects were conducted. The first project involved a systematic review to investigate the validity of using teledentistry in dental practice. The second project examined demographics, individual characteristics, and prior experience with teledentistry associated with U.S. dental students' intention to use teledentistry in their dental practice. The final project utilized the unified theory of acceptance and use of technology model (UTAUT) to predict the future use of

teledentistry by evaluating U.S dental students' behavioral intention to use teledentistry in practice.

The systematic review confirmed that a teledentistry oral diagnosis was comparable to face-to-face diagnosis and suggests the need for methodologically designed studies with appropriate statistical tests to further investigate the validity of teledentistry. Project II results indicated that dental students with prior teledentistry experience were more likely to utilize this technology in their future practice. Project III identified that the UTAUT model significantly predicted dental students' behavioral intention to use teledentistry. All the UTAUT constructs were significantly associated with dental students' behavioral intention. Findings from these three projects indicate that exposure to teledentistry while in dental school increases the likelihood of use as a licensed dentist.

This dissertation is dedicated to my beloved family who always gave me continuous support.

To my parents for their ongoing sacrifices.

To my country who gave me this opportunity to pursue the PhD degree**.**

To myself in appreciation of my effort.

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CHAPTER I
INTRODUCTION

Background

Most developed countries are experiencing challenges related to their healthcare systems. These challenges include access, affordability demand for health care, efficiency of services, and limited financial support.[1] The rapid development of information technology (IT) offers a new avenue for addressing some of these challenges.[1,2] Information technology has been rapidly integrated into healthcare systems to address accessibility and delivery of care challenges to remote communities.[1]

Technology use in healthcare began over 50 years ago with the purpose of delivering healthcare to patients in remote areas.[3] Telemedicine- or telehealth- is a good example of using IT for medical services. Telehealth can be broadly defined as the exchange of medical information from one place to another via electronic communication in order to improve health conditions of patients.[4] Telehealth exchanges information using applications such as video, smartphones, email, pictures, and any other communication system technologies.[5] There has been increased interest in the use of telehealth in healthcare services. Telehealth technology has contributed to increased access to health services, reduced costs of healthcare treatment, and reduced equipment costs.[6-9] Therefore, telehealth has been found to improve access to healthcare and enhance the quality and efficiency of health services.[10,11]

The use of telehealth in dentistry is known as teledentistry and was introduced after telehealth had been practiced throughout the world for years.[12,13] The concept of teledentistry was first developed in 1989 at a conference in Baltimore that focused on the use of dental informatics to deliver dental care.[13,14] Teledentistry began with phone calls between dental

professionals and patients, as well as dentists seeking consultations from dental specialists or medical providers.[15] Today, current technology allows dental experts to receive different forms of media, such as dental charts, photographs, radiographs, and written records that allow for consultation with dental specialists.[15,16] Therefore, telehealth in dentistry- teledentistry- can be defined as using telecommunication to exchange dental information, images, and video over extensive distances for consultation between and among patients, general dentists, dental specialists, and other care providers.[15]

Telehealth in dentistry can improve access to oral care and reduce the prevalence of oral diseases, such as dental caries.[17] Dental caries is the most prevalent oral disease, particularly in children.[18] For 2015-2016, the prevalence of treated and untreated dental caries among youth aged 2-19 was 45.8%, and about 13% of dental caries were untreated.[19] Lack of dental visits is associated with dental caries.[17] Therefore, improving access to dental care and facilitating dental visits for individuals may help to decrease the prevalence of dental caries. Telehealth technologies can improve access to dental care and increase the opportunity of oral assessments for underserved populations, which has the potential to increase the treatment of dental caries.

Teledentistry, as a new technological modality, has not been as widely accepted in dentistry as in medicine, and the application and development of teledentistry is limited in the U.S.[20,21] One of the main reasons for the failure of implementation of technology, such as telehealth, is an insufficient understanding of how individuals accept information technology.[22] User acceptance of IT is a critical factor in the successful implementation of this new healthcare modality.[23] Understanding factors associated with the acceptance and non-acceptance of telehealth in dental practices could help improve access to dental services. Therefore, an

investigation of the facilitating factors and barriers that predict the acceptance of teledentistry among dental professionals is needed.

Statement of the Problem

A shortage of dental professionals and barriers to access dental care services are challenges to improving oral health and decrease the burden of dental diseases.[24,25] Remote regions suffer from a significant shortage of dental professionals and those who live in rural areas encounter difficulties in accessing general dental care and finding dental specialists.[8,16,26] In the U.S., there are more than 56 million individuals who live in dental health professional shortage areas.[27] These underserved areas need at least 9,951 dental practitioners in order to overcome the overwhelming obstacles to oral care access.[27] The number of dentists is inversely proportional to the distance from urban areas.[27,28] About 70% of rural areas have an unmet need for dental professionals; limiting access to dental care for individuals with considerable dental care needs.[27,29] People who live in rural areas bare challenges such as poverty, limited insurance coverage, no dental providers, and travel long distances to obtain dental care.[30] Hence, inequity in oral health exists where underserved populations experience greater oral diseases.[31]

Accordingly, finding new methods to facilitate communication between dental professionals and patients becomes essential to the improvement of oral health care services. The use of telehealth in dentistry is an approach for delivering oral care and facilitating consultations between dental professionals and patients.[20,32] Use of teledentistry would improve virtual communication and diagnosis between dental professionals and patients without the need for physical presence.[33]

Health professionals' acceptance of technology is a key factor in the successful implementation of telehealth interventions,[34] thus provider acceptance is imperative for utilization. There is a strong perception that technology is going to offer improvements over the current system;[35] however, the adoption of technological interventions cannot be achieved if health professionals are unwilling to use the system. Therefore, it is necessary to understand future dentists' willingness and readiness to implement new technology and effectively incorporate it into their future practices.

User acceptance and adoption behavior of technology have been examined in healthcare settings such as telemonitoring, telemedicine, electronics medical records, and telerehabilitation.[34,36,37] However, to our knowledge, no studies have examined factors associated with the behavioral intention (BI) of dental students' use of teledentistry. Identifying predictors related to dental students' intention to use teledentistry is important for future planning and curriculum development. Hence, it is necessary to conduct a study that would investigate factors affecting the implementation of teledentistry from dental students' perspectives to fill these gaps.

Purpose of the Study

The main purpose of this dissertation was to identify barriers and facilitating factors related to the future utilization of teledentistry. To achieve this main goal, three projects were conducted. The validity of teledentistry is a critical factor that might impact the adoption of teledentistry. The first project was to systematically review the literature to investigate whether previous studies addressed the validity of teledentistry use in dental practice (Project I). The second project explored the association of demographic factors, individual characteristics, and prior experience with teledentistry of U.S. dental students' intention to use teledentistry in their future practice (Project II). Lastly, the final project sought to predict the future intention to use

teledentistry among 4th-year dental students by utilizing the unified theory of acceptance and use of technology (UTAUT) model (Project III).

Theoretical Framework

Several models and theories have been developed in psychology, sociology, and individual behavior to explain the adoption and use of technology.[38,39] To provide a better evaluation of the barriers and facilitators of the intention to use teledentistry among dental students, this study utilized the UTAUT model as a theoretical framework.[38] The UTAUT model was used to explain and predict dental students' BI to use telehealth.

The Unified Theory of Acceptance and Use of Technology

The UTAUT model is one of the most common models used when studying new technological adoptions in healthcare settings by healthcare professionals.[40,41] The model attempts to explain BI to use technology in order to predict future usage behavior. The UTAUT constructs were developed after reviewing and combining eight different models that have been widely employed to assess technology usage behavior. The unified models are the Technology Acceptance Model (TAM), Theory for Reasoned Action (TRA), Motivational Model (MM), Theory of Planned Behavior (TPB), Combined TAM and TPB model (C-TAM-TPB), Model of PC Utilization, Social Cognitive Theory (SCT), and Innovation Diffusion Theory (IDT).[38] Subsequently, the UTAUT model was validated and found to account for 70% variance of individuals' BI, while the other models only explained 40% of behavioral intention.[38]

The UTAUT model represents factors that influence individuals' intention and implementation of healthcare technology. Venkatesh *et al*.[38] suggested that the UTAUT model should include four constructs as direct predictors to assess individuals' BI of technology

acceptance. Thus, the BI of using a particular technology is influenced by four main determinants as illustrated in Figure 1 and include: 1) performance expectancy (PE) or an individual's perceptions about the usefulness of a system, 2) effort expectancy (EE) is the degree individuals believe that a system would be easy to use, 3) social influence (SI) or user perception that important others such as friends believe that a particular system should be used, and 4) facilitating conditions (FC) which is an individual's perception that technical infrastructure is available to support use of the technology (Table 1). In essence, individuals are more likely to use technology when they perceive the usefulness of a system, believe it is easy to use, have support from significant others such as team members or colleagues, and when infrastructure is available.[38]

Moreover, the UTAUT model suggests four moderating variables (age, gender, experience, and voluntariness) that moderate the relationship between the main predictors and the behavioral intention. The UTAUT model was adopted for this study to determine constructs that significantly predict the acceptance and intention of dental students to use teledentistry (Figure 1).

The Application of UTAUT in Healthcare

Increasing the worldwide application of IT in healthcare organizations has led to the identification of users' acceptance as a significant factor on the likelihood of adoption.[42-44] The UTAUT model was recently contextualized to understand adoption of technology in healthcare settings.[36,37]

Liu *et al.*[37] utilized the UTAUT model to examine factors that influence the acceptance and BI to use technology for rehabilitation by occupational therapists in Canada. A self-

administered paper questionnaire was adopted from previous studies that applied the UTAUT model. The questionnaire was sent to 138 participants of which 91 returned the questionnaire for a response rate of 64%. By using partial least square (PLS) for the analysis, the researchers found that performance expectancy was the most important predictor for determining occupational therapists' acceptance and use of technologies ($\beta = 0.585$, $p < 0.01$). These findings regarding performance expectancy were consistent with Rho *et al.*[40] ($\beta = 0.345$, $p < 0.01$) who aimed to find factors that would predict the use of telemedicine by diabetic patients. They concluded that the stronger the perceptions that the technology would help users or healthcare professionals improve their performance or outcome, the greater the BI to use telemedicine.

Some studies found significant relationship between EE, SI, and BI.[40,41,45] Rho *et al.*[40] also found that SI ($\beta = 0.246$, $p < 0.05$) and EE ($\beta = 0.227$, $p < 0.05$) were significant predictors of the participants' intention to utilize telemedicine services. The more effort required when using and implementing technology, the less likely users are to continue use.[40,41,45] Hence, if dental students believe teledentistry is easy to use, future usage and adoption rates are expected to increase accordingly.

However, Liu *et al.*[37] study was similar to Asua *et al.*[36] study that also used the UTAUT model to examine nurses' acceptance of hospital information systems (HIS) in Iran. Data was collected through a cross-sectional survey of about 300 nurses. All the UTAUT constructs (PE, EE, SI, and FC) were found to be significant predictors of nurses' BI to use a HIS, whereas PE was the strongest factor on the participants' intention to use. Asua *et al.*[36] found that FC was the most powerful predictor of medical professionals' intention to use a telemonitoring system, and FC also had a positive effect on the behavioral intention. Therefore, it was concluded that participants are more likely to consider telehealth to be a helpful system if they believe that it has

a vigorous infrastructure to support the use of telehealth.[36] The effects of UTAUT constructs on BI explained 72% of the variance of nurses' BI to use health information system. Accordingly, the prediction power of the UTAUT constructs was significantly strong and accounted for the nurses' intention to use hospital information system.

The above studies had some limitations.[37,36]While they found a significant relationship between the UTAUT constructs and BI, the HIS was found to have a limited application in Iran's hospitals. The target population included participants from a limited number of hospitals, limiting the external validity. Similarly, the study by Liu *et al*.[37] was conducted only in one hospital. For that reason, the generalizability of the study was limited. Thus, the goal of this dissertation was to invite all the American dental schools to participate to overcome this limitation. Another limitation of a previous study was that 90% of the participants were female.[36] Gender differences were found to be related to BI of acceptance and use of technologies.[38] Pointing to the need for an equal or comparable number of males and females in a sample to observe gender differences.

The aforementioned studies[36,37,40,46] strongly suggest use of the UTAUT model in healthcare studies to achieve a better understanding of the adoption of telehealth in oral care. The model significantly predicted the BI to use technology by healthcare professionals and patients. Therefore, this study utilizes the UTAUT model to provide more evidence-based theory that would increase knowledge about the future use and adoption of telehealth in dental practices.

Gap in the Literature

This study aims to: 1) determine dental students' perceptions of telehealth in dental practices in an effort to improve dental care services and communication issues, 2) predict dental

students' willingness to use telehealth, and 3) determine dental students' perceived obstacles related to use of telehealth in dental practice. User acceptance and adoption behavior of technology have been examined in healthcare settings such as telemonitoring, telemedicine, electronic medical records, and telerehabilitation.[34,36,37] However. the literature revealed a lack of studies that investigated dental students' intended use of teledentistry in their future professional practice. It is still unclear to what extent dental student professionals are willing to adopt and accept this technology for dental practices. Therefore, this study was designed to investigate barriers that could affect teledentistry implementation from the viewpoint of dental students.

Additionally, this study utilizes the UTAUT model as the main framework. While the UTAUT model has been utilized to predict health professionals' BI in several healthcare fields,[36,37,41] the application of a theoretical framework to the acceptance of telehealth technology by dental students has not been conducted. Therefore, this project is innovative in its use of a theoretical approach to investigate dental students' BI to use teledentistry. The model provides information and factors necessary for understanding the implementation of telehealth in dental practices. The initial efforts of the project aimed to find an efficient and effective evidence-based method to identify barriers for application of telehealth in dental practice.

Moreover, for health services research, it is crucial to investigate factors that will improve the quality of health for people. A primary objective of Healthy People 2020 is to increase the use of health information technology in order to improve health outcomes, increase health quality and achieve health equity.[47] With the concern of adopting telehealth technology in dentistry, the question arises as to the intention of dental students to utilize IT in dental practice. Therefore, understanding dental students' intention is essential in creating dental school curricula

that encourage the use and acceptance of telehealth among future dental professionals, fill the literature gap, and meet Healthy People 2020 goals.

As a result, the findings from this research will fill the literature gap by focusing on dental students as the end-user of telehealth and viewing the problem from a psychosocial perspective of the end-user utilizing the UTAUT model. Therefore, this study is the first to develop and validate a socio-behavioral approach related to intention to use telehealth among dental students.

Specific Aims and Hypotheses

Project I

Aim 1: To systematically review the literature in order to investigate the presence of evidence to support the validity of telehealth in dental practices**.**

Hypothesis 1: the literature will reveal strong evidence that supports the validity of telehealth in dental practices.

Project II

Aim 2: To determine the association of demographic factors, individual characteristics, and previous experience with dental students' intention to use teledentistry.

Hypothesis 3.1: There are no significant differences with demographic characteristics (age, gender, ethnicity, race, degree before dental school, type of dental institution, geographic location) and students' BI to use telehealth in dental practice.

Hypothesis 3.2: Participants who have telehealth experience or exposure to telehealth are more likely to use teledentistry compared to those who have no experience.

Project III

Aim 3: We seek to utilize the UTAUT model to predict dental students' BI to use telehealth in dental practices.

Hypothesis 3.1: Performance Expectancy is positively associated with dental students' behavioral intention to use teledentistry.

Hypothesis 3.2: Effort Expectancy is positively associated with dental students' behavioral intention to use teledentistry.

Hypothesis 3.3: Social Influence is positively associated with dental students' behavioral intention to use teledentistry.

Hypothesis 3.4: Facilitating Conditions are positively associated with dental students' behavioral intention to use teledentistry.

Hypothesis 3.5: Overall, the UTAUT model would significantly predict dental students' behavioral intention to use telehealth.

Definition of Terms

- **Behavioral Intention (BI):** an individual's likelihood to use the system.[38]
- **Effort Expectancy (EE):** "defined as the degree of ease associated with the use of the system."[38]
- **Facilitating Conditions (FC):** "are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of a system".[38]

- **Performance Expectancy (PE):** "is defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance".[38]
- **Social Influence (SI):** "is defined as the degree to which an individual perceives that important others believe he or she should use the new system".[38]
- **Teledentistry/Telehealth:** is defined as using telecommunication technology, electronic medical records, video, and digital images to facilitate dental services delivery for distant or isolated people or for consultations among.[15]

Assumptions

For Chapter III and IV:

- Dental students have a basic level of knowledge and awareness of telehealth.
- Participants understand the definition of telehealth/teledentistry.
- Participants will provide honest and accurate answers when completing the survey.
- Participants will be able to completely understand the content of the survey and answer all the questions.

Limitations

Findings from the three studies were influenced by several factors. First, the study sample consisted of a convenience sample of fourth-year U.S. dental students. Thus, the demographic and individual characteristics of the study sample may not be reflective of all dental students. Therefore, generalization of findings to all U.S. dental students should be cautioned. Given, these limitations, this was the best approach to reach all U.S. dental schools in order to increase study

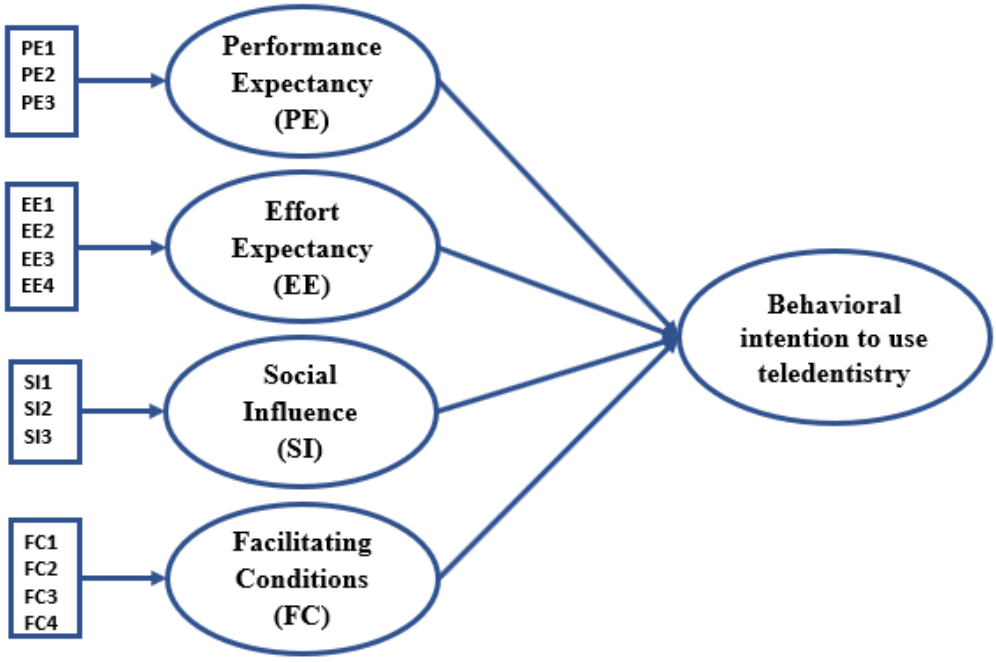
participants. Moreover, to attain a sample of sufficient size, it is very crucial to contact many prospective subjects; thus, the larger the sample size, the more statistical power to find significant relationships among variables.

Second, this project is only a study of the perceptions of dental students to use telehealth in dental practice instead of the behavior of actual use. There is a probability that participants' behavior may change after graduation. Third, the study is a descriptive cross-sectional study and cannot establish causality. Fourth, the study utilized a self-administered questionnaire that could have posed bias in participants' responses depending on their ability to understand the questions and willingness to answer.

Table 1. Definitions of the theoretical constructs of the UTAUT model.[38]

Construct	Definition
Performance Expectancy	The degree to which an individual believes that using the system will help to improve job performance
Effort Expectancy	The degree to which an individual believes of the ease associated with the use of the system
Social Influence	The degree to which an individual perceives that important others believe he or she should use the new system
Facilitating Conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system

Figure 1. The proposed research adopted from Venkatesh *et al.*[38]



CHAPTER II

REVIEW OF THE LITERATURE

PROJECT I: A SYSTEMATIC REVIEW ON THE VALIDITY OF TELEDENTISTRY[48]

Introduction

Teledentistry emerged as a part of telemedicine following years of global telemedicine practice. In 1989 at a conference in Baltimore Maryland focused on the delivery of dental care using dental informatics, the term, "teledentistry", was introduced.[49] Teledentistry is defined as using telecommunication technology, electronic medical records, video, and digital images to facilitate dental services delivery for distant or isolated people or for consultations among specialists.[50] Teledentistry does not only encompass technology or a varied set of related forms of technologies; rather, it is a collection of clinical processes and organizational arrangements combined with technologies. Incorporating teledentistry in dental health services has the potential when used appropriately to improve access, improve health education, enhance the quality, efficiency, and effectiveness of dental health services.[49]

There are barriers that could slow the adoption of telemedicine technology such as reimbursement issues, license regulations, costs, limitations in physical examinations and equipment required.[50,51] Reimbursement is one of the main challenges that slow the development and adoption of teledentistry. Medicaid reimbursement is available in some cases providing limited compensation limiting adoption of this technology by dental professionals in their dental practices.[21] The use of telemedicine technology to deliver healthcare services has contributed to a reduction in the cost of healthcare treatment for patients and equipment for providers.[52] Yet, teledentistry has not been as widely accepted as telemedicine even though the use of teledentistry increases access to dental services for those who live in rural areas.[26]

Systematic reviews of teledentistry, adoption and use are few. The first systematic review published in 2013 comprehensively reviewed all published studies in teledentistry.[53] A second systematic review focused on the application of teledentistry in three areas; clinical outcomes, utilization and costs.[24] The third reviewed the accuracy of dental images for the diagnosis of dental caries.[54] It is crucial to assess the validity of teledentistry in the delivery of oral care before making a decision to adopt the technology and implement use in dental practice. No previous systematic reviews that evaluate the validity of teledentistry have been published to the best of our knowledge. Evidence that teledentistry is valid in the delivery of oral care may change policymakers and dental professionals' decisions leading to adoption of the technology. Thus, the purpose of this systematic review was to evaluate the validity of teledentistry for examination and diagnosis.

Methodology

Information sources and search strategy

The primary investigator performed a systematic search of the literature for studies assessing the validity of teledentistry without time limitation during June 2016. Search filters were to limit retrieval to peer-reviewed journal articles published in English. Books, editorials, reviews, commentary reports, dissertations, unpublished materials, and letters to the editor were not included in the search. Three databases to retrieve articles related to the purpose of this study were: PubMed/Medline, Scopus, and EBSCO host (EBSCO host included several databases such as CINAHL, Dentistry and Oral Sciences, ERIC, Academic Search Complete, etc. Search terms with different alterations included the following: "teledentistry and validity," "teledentistry and reliability," "telemedicine or telecare or telehealth or teleconsultation and validity and dentistry

or dental." The Boolean operator "AND" and "OR" were used to combine the search key terms (Table 2).

Study selection and data extraction

The first step was to evaluate each article identified from the database against the inclusion criteria. Second, two reviewers independently screened each article. Three articles required discussion between the reviewers to determine inclusion. Fifty-eight articles were reviewed by title and abstract. Forty-four articles removed after reviewing titles and abstracts. Full text articles were retrieved on the remaining 14 publications. Abstracts found to be relevant were obtained for review. Full text of thirteen articles that met the inclusion criteria were retrieved and reviewed for eligibility. All the articles were analyzed, discussed, and reviewed by 2 investigators. Figure 2 shows the flow chart of article selection.

Inclusion and exclusion criteria

Articles were included if they met the following criteria: 1) related to telehealth or teledentistry, 2) written in English and full text available, 3) compared teledentistry to visual examination or gold standard (GS) examination, 4) used any form of telecommunication or telehealth for the examination, and 5) had clear statistical tests to evaluate validity. The following articles were excluded: 1) not related to teledentistry or telehealth, 2) pilot studies due to small sample size or the main study was included in the systematic review, 3) studies with insufficient or missing information to be included in the study, 4) full text was unavailable, 5) insufficient data analysis, 6) no description of gold standard, and 7) only a published abstract was available. Since this systematic review focused on the validity of teledentistry when

compared to the GS or clinical assessment, there was no restriction with respect to the study design, population characteristics and sample selection.

Quality assessment

Two reviewers independently assessed the quality of methods for the included studies. The "Quality Assessment of Studies of Diagnostic Accuracy" (QUADAS) tool was used to assess the methodological quality of the validity for studies included in this systematic review.[55] The QUADAS tool has 14 components with a rating of "yes," "no," or "unclear" for each component. Reviewers discussed each component of the QUADAS to resolve any differences. According to the QUADAS guidelines, a study is considered high quality if the QUADAS score was more than 60%.[56] No studies were excluded based on the quality assessment.

Statistical considerations

The focus of the systematic review is to assess the literature on the validity of teledentistry. Statistical tests are crucial to determine the validity of research findings in any quantitative study and therefore, the need for appropriate statistical tests to measure validity in the reviewed articles. Agreement between teledentistry examination and visual examination as the GS are also important to assess validity. Statistical tests to measure validity such as Kappa, specificity and sensitivity needed to show the percentage of true or false agreement.

Results

Figure 2 shows a total number of 79 studies identified from database searches: 49 studies from EBSCO Host, 18 from PubMed, and 12 from Scopus. Once duplicate articles were removed, 58 potentially relevant articles were screened based on their titles and abstracts.

Fourteen of these relevant articles met the criteria for a full-text review. After reviewing the 14, only nine articles met the inclusion criteria and were included in the review.

Characteristics of the included studies

Most of the nine publication dates were 2002 to 2016. Research occurred in several countries: three from the USA, two in the UK, and one in each of the following countries: Brazil, Portugal, Australia, and Germany. Four studies were in pediatric dentistry, two in general dentistry, one in maxillofacial radiology, endodontics and orthodontics. Articles were published in different journals and one book. Most journals were not related to telehealth or teledentistry (Table 3).

Only two studies used random sampling to recruit participants.[57,58] The remaining studies used convenience sampling; however, not all the studies involved human participants, one paper used facial radiographs, and another study used extracted teeth as the basis for comparison. In those with human participants, the number of participants ranged from 29 to 327 (Table 3).

Four studies were conducted on children and young adults from 1 year to 19 years of age.[57,59-61] The study which used facial radiography did not include the age of participants.[62] Two studies recruited subjects of different ages as the age of the individual was not the variable of interest. The variables of interest were the accuracy and validity of the teledentistry diagnosis.[58,63] An additional study used extracted comprised teeth from adults aged between 40 and 70 years old.[64] The majority of studies were cross-sectional design performed in a specific time, and there were only two randomized control studies.[57,58] Eight studies were conducted in a clinical setting and only one in a laboratory (Table 3).[64]

Quality assessment of validity studies

The QUADAS tool was used to assess each article (Figure 3). The results of the assessment varied from 9 to 13 out of 14 items indicating that the reviewed studies met 60% or more of the quality assessment items. Table 4 shows the results of the quality assessment appraisal. Most of the studies addressed the validity of teledentistry technology in dental diagnosis and did not include random sampling; instead, convenience sampling was used which is unlikely to be representative of the population.

The intervention

There was some variation among the studies in the type of equipment used for teledentistry. Four out of nine studies used an intraoral camera to gather images of teeth for later examination.[33,57,60,64] Three studies used a digital extra-oral camera,[58,59,61] and one study used a smartphone camera.[63] All of the included studies utilized store and forward mode- asynchronous- and no study used real-time communication or video conferencing –synchronous.

The gold standard reported most often was the traditional visual examination. Methods and items used for visual examination varied among the studies. Methods and items used for examinations included the following: use of light soucrce,[57,59] sterilized exploration kit,[61] probe,[59] air syringe,[59] mirror,[33,57,59,60] explorer,[33,57] and palpation.[33] Visual clinical examination for dental caries assessment was used in four studies.[57,59,60,63]

The validity of teledentistry compared to visual examination in the decision accuracy of referrals was reported.[58,59,61] Diagnosis from a radiograph (GS) was compared to the diagnosis of the same radiograph accessed remotely through the telemedicine system.[62] Treatment decisions based on a dentist or allied dental professional's visual assessment as GS to virtual examination have been reported.[33] An endodontic study captured, intraoral images of the entire pulp canal

floor of extracted third molars for later visual examination. Remote assessment of canal orifices compared to the histological images of the dental pulp (GS) determined validity.[64]

Personnel varied in the studies. General dentists performed both the GS and teledentistry examination possessed a range of experience.[33,57,60] Oral and maxillofacial surgeons, and accident and emergency personnel assessed maxillofacial fractures from radiographs.[62] Two dental therapists performed the teledentistry examination in another study,[63] and an oral surgeon and an orthodontist conducted the GS examination in two studies.[58,61] Other studies reported only that the examination was performed by a dental examiner, researcher, or observer with no specifics as to experience or type of examiner.[59,60,64]

Statistical analysis

Table 5 shows sensitivity and specificity reported by the majority of studies. Eight out of nine reported calculated sensitivity with values ranging from 25% to 100%, and seven with specificity values from 68% to 100%. Moreover, positive predictive value (PPV) of teledentistry examinations ranging from 57% to 100% and negative predictive value (NPV) ranging from 50% to 100% were reported. Five studies used the Kappa statistic to evaluate agreement between teledentistry and visual examinations (Table 5).

Agreement between the GS examinations and teledentistry examinations ranged from 46% to 93%. One study found the mean difference of decayed-filled surface scores between the teledentistry and control groups was not significantly different ($p > .001$).[57] In the area of maxillofacial radiology,[62] the diagnosis of facial fracture by plain radiograph was more accurate than images sent by a telemedicine system. Images with low quality were poorly diagnosed by a telemedicine system (sensitivity 25%-100%, specificity 68%-100) (Table 5).[62]

Discussion

The aim of this systematic review was to explore the body of literature to determine the diagnostic validity of teledentistry for use in dental practice. System validity reflects the degree of accuracy of measuring what it is to measure.[65] Investigating teledentistry validity is an important step in determining whether teledentistry is as accurate as traditional oral examinations. The validity of a teledentistry system is crucial because clinical decision making through telecommunication may not be accurate as face-to-face traditional examinations. Moreover, there is a shortage of studies with consistent methods to assess the validity of teledentistry applications. For this systematic review, nine studies met the inclusion criteria to assess the validity of teledentistry compared to a traditional visual examination as a gold standard.

Furthermore, a cross-sectional design was used with only two randomized controlled trials that divided participants into control and intervention (teledentistry) groups.[57,58] The randomized controlled trial is preferable and therefore, provides stronger evidence to support the validity of teledentistry. Both studies using the randomized control trial reported the teledentistry group not significantly different from the control group which supported the validity of teledentistry.[57,58]

Table 5 shows most studies reported scores higher than 75% for sensitivity and specificity indicating teledentistry screening could be comparable to traditional examination. However, few studies reported low sensitivity scores (< 60%).[59,62,63] which indicates weak comparability to traditional examination. Thus, the majority of the studies reported the value of specificity and NPV were higher than sensitivity and PPV, indicating more true negative agreement between visual examination and teledentistry. These results mean that teledentistry

assessment is more consistent with the visual examination in the assessment of sound teeth without any lesion.

Additionally, Kappa statistics revealed that there were moderate to almost perfect measures of agreement between teledentistry and the visual examination (Table 5). Some studies reported examiners found it difficult to detect oral lesions using photographs as detail on all teeth was not clear. Face-to-face interaction with patients was reported as an important factor that could result in the moderate agreement between teledentistry screening and visual examination. However, the Kappa findings strengthen the assumption that the two modalities are comparable methods for use in dental examinations. These findings were also consistent with other studies investigating the reliability of teledentistry.[66,67]

More than half (n =5) of the studies found teledentistry examination comparable to the traditional clinical examination when screening for dental caries. The teledentistry system was able to transmit a clear picture of teeth with dental caries to a doctor for the purpose of caries assessment. Interproximal caries were not evaluated in these studies because it might need radiographs to provide the best diagnosis. Dental caries is one of the most prevalent chronic diseases causing tooth loss, pain, time away from school or work, and decrease in quality of life.[68] Also, dental caries is one of the most prevalent diseases among children. According to the Centers for Disease Control and Prevention, 28% of children between 2 and 5 years are affected by dental caries.[69] No statistically significant differences in early childhood caries detection between teledentistry and visual examinations have been reported.[57,60] therefore, teledentistry is a viable technology for early diagnosis of dental caries among children. Moreover, teledentistry is cost-effective for dental caries assessment to reduce the epidemic of dental caries among the population.[60]

Teledentistry examination can be useful in rural areas where people cannot access dental services or specialists. Methodology in many of the articles transmitted oral images from remote sites for teledentistry screening. Distance diagnoses of oral lesions, such as dental caries, provided very good sensitivity and specificity scores.[57,60-63] Teledentistry is not only an effective tool for dental examinations, it can increase access to dental specialist consultations and subsequent care.[11,50] Teledentistry provides access to dental care, reduces travel miles, costs, time and suffering.[8,11,70] Berndt F. *et al.*[71] found that interceptive orthodontic treatments delivered by trained general dentists remotely supervised by orthodontists through teledentistry are a feasible approach to treat the severity of malocclusions for underserved children with limited access to the specialist.

A twelve-month teledentistry trial was conducted in general dentistry practices to evaluate the cost-effectiveness of teledentistry.[70] The study obtained costs associated with a visit to a dental practice, loss of productivity time and accommodation expenses. Patients could lose about 12 to 25 hours of productivity by visiting distance dental offices. The study found that patients who live in rural areas could save about $1,060 by implementing teledentistry in dental practices.[70]

Time management is important to providers; therefore, teledentistry could improve time utilization to assess needs and perhaps provide care to those in rural areas. Teledentistry is a useful tool for consultations between providers providing electronic access to a patient's oral condition before the appointment time. The time saved would provide more time for treatment.[20] The findings of this review support dental professionals not being present physically with a patient to perform an oral assessment and treatment needs. This finding is consistent with a teledermatology study that reported a 69.05% agreement between teledermatology and face-to-

face diagnosis; representing a high level of validity and considered a useful method for the diagnosis of distance patients reducing the face-to-face consultations 40%.[72]

The intra-oral camera captured the dental detail for remote diagnoses in most studies (Table 3). Intraoral cameras are not available in every practice; however, a smartphone camera can obtain images for remote diagnosis or assessment. Only one study used the mobile phone camera in this review.[63] Transmission of patient data over the internet may require encryption. Further, healthcare personnel should not use personal camera phones for patient data.

Most importantly, the quality of the photographic image is key to the validity for teledentistry adoption and application. Poor quality images reported lower sensitivity and specificity scores than higher quality photosgraphs.[62] Low photographic quality might prevent the dental professional from accurate identification of treatment needs. An advantage of using good quality photographs obtained during a teledentistry assessment is that magnification on the computer can provide better detail of the image. Magnification and illumination provided by teledentistry were contributing factors to better accuracy in the examination over the visual examination.[60,73,74] Findings of the present review were consistent with the findings of a systematic review to investigate whether photographic screenings were comparable to visual clinical examination.[54] Three studies in their review found photographic analysis superior to visual clinical inspection while six studies found the two methods comparable.[54] Teledentistry use requires appropriate training of personnel to obtain and review quality images. To implement an accurate teledentistry system training and quality equipment should be used to deliver accurate images to dental professionals.[75]

Differences among dental professionals exist concerning the use of teledentistry. Some professionals reported that they were not satisfied making a diagnosis using telecommunication

images without clinical information.[33,58] Access to patients' information is one of the main limitations that could affect the validity of teledentistry. Face-to-face examinations provide an opportunity to talk with patients to obtain information to assist with diagnosis. Lack of information could decrease the dental professional's confidence in making a diagnosis using a teledentistry system only and therefore, decrease the validity score of teledentistry. With the availability of video conferencing, a consultation could occur in real-time or after the review of oral images.

Furthermore, experience of the dental professional plays an important role in the ability to diagnose using teledentistry. Remote diagnosis by experienced professionals provided more accurate diagnosis than those with less experience.[64] Experience could affect the validity of teledentistry and increase or decrease the sensitivity or specificity scores. A teledentistry system could assist experienced specialists with consultations, provide a more accurate diagnosis to patients and reduce untreated disease. These findings were consistent with previous studies that found no differences between intra-examiner agreements in treatment decisions when using teledentistry.[33,66,67]

Limitations and Future Research

While the number of teledentistry studies is increasing, few use research methods and statistical analyses that can provide strong evidence for comparison of traditional visual examination to teledentistry examination. The searched databases and the search terms might not identify all the studies published on teledentistry. The included studies were different in the area of application, settings, methods, equipment, and examiners. Therefore, because of the methodology variability among studies, it was difficult to generalize the findings of this systematic review. Future studies need to look at standardization of cameras, examiners, settings,

and types of statistical analyses to facilitate comparisons. Further research is essential to examine the accuracy of using live video in conjunction with photo conferencing for dental diagnosis and consultation. Further investigation is needed to enhance the quality of images to improve the validity of teledentistry. The present review suggests that more investigation to foster the validity of teledentistry outside the clinical setting is needed, such as use of mobile phone cameras and a cost analysis to address savings from teledentistry.

Conclusions

Teledentistry examinations are valid, feasible, and comparable to visual examination for oral screening. Studies concluded that dental professionals make valid decisions about treatment based on a virtual examination. One study reported a loss of picture quality when using the telecommunication system that could decrease diagnostic confidence, sensitivity, and specificity. Nevertheless, a diagnostic collaboration between dental specialists using teledentistry could improve dental treatment and access to care.

Teledentistry is a valid tool to reduce inappropriate orthodontic referrals. Teledentistry use in general dentistry does not appear to affect judgment of the dental professional significantly when compared to the judgment with a visual examination. Moreover, the same conclusion can be reached and appropriate decisions regarding needed treatment and referral using the two modalities. Teledentistry could be a comparable tool to face-to-face technology for oral screening especially for school-based programs, caries assessment, referrals, and teleconsultations. Some studies reported low scores of sensitivity for teledentistry when compared to traditional clinical examination. Therefore, the validity of teledentistry in dental specialties requires further research

Table 2. Search terms and databases

Electronic Databases	PubMed/Medline, EBSCO Host and Scopus		
Search Terms	Teledentistry Telehealth Telecare Telemedicine	Validity Reliability	Dentistry Dental Oral health

Table 3. Characteristics of the included studies in the systematic review

Authors, Year,	Purpose	Area	Gold (GS) Standard	GS Examiners	TD Examination	TD Examiners	Sample	Design	Subjects
Jacobs *et al.*, (2002).[62]	To assess the accuracy of diagnosis of facial radiographs compared with the same radiographs viewed through the telemedicine system	Maxillo-facial radiology	Plain radiographic Images	8 OMFS, 8 Accident and emergency doctor	Radiographs viewed through telemedicine	Same Examiners -2 weeks washout period	Convenience sampling	Cross-sectional	20 facial radiographs
Estai, *et al.*, (2016).[76]	To assess the validity and reliability of intraoral images for dental screening	General dentistry	Visual Examination	Dentist	500 Images by smart phone	2 Australian registered MLDPs	Convenience sampling	Cross-sectional	100 patients, (adult and children)
Morosini (2014).[59]	To assess the validity teledentistry system to screen for the presence of dental caries	Pediatric dentistry	Visual examination (DMFT)	Researcher	5 intraoral images/patient	2 distant examiners	Convenience sampling	Cross-sectional	102 Juvenile offender 15 – 19 years of age
Kopycka *et al.*, (2007).[77]	To assess the feasibility and reliability of using intraoral images and teledentistry to screen children for oral disease	Pediatric dentistry	Oral Examinations (dfs)	Dental examiner	Six intraoral images/ participants	Same Examiner -2 weeks washout period	Convenience sampling	Cross sectional	50 preschool children 4-6 years old
Amavel *et al.*, (2009).[61]	To investigate the validity of teledentistry to diagnose children dental problems remotely using non-invasive photographs	Pediatric dentistry	Traditional in person dental consultation	Experienced dentist	Oral images	4 dentists	Convenience sampling	Cross sectional	66 children 4- 6 years old

Table 3. Continued

Authors, Year,	Purpose	Area	Gold (GS) Standard	GS Examiners	TD Examination	TD Examiners	Sample	Design	Subjects
Mandal *et al.*, (2005).[78]	To evaluate the validity of teledentistry for screening new patient orthodontic referrals	Ortho-dontics	Clinical decision, accept or not accept referral	Orthodontist	TD decision based on images	Same examiner	Random sampling for dental practices	Randomized controlled trial	327 patients from 15 dental practices
Namakian, *et al.*, (2012).[33]	To evaluate the agreement of a dentist's decision about dental treatment reached through visual versus a virtual examination	General dentistry	In-person examination and decision	3 general dentists	Virtual examination and treatment decision	Same examiners At least 3 weeks washout period	Convenience sample	Cross-Sectional	29 adults, 20 -68 years old
Brullman *et al.*, (2011).[79]	To evaluate the ability of dental examiners to remotely locate dental pulp orifices from an images.	Endodontics	Histological slices of the canal orifices	Experienced oral surgeon under a light microscope	Photograph of the entire pulp, canal floor	20 independent observers	Convenience sample	Cross-sectional	50 Extracted teeth of patients aged 40-70
Kopycka *et al.*, (2013).[57]	To compare the effectiveness of teledentistry versus the traditional examination in screening early childhood caries	Pediatric dentistry	Traditional visual examination, dfs	General dentist	Intra oral images	Same Examiner	Random sampling	Cohort longitudinal study – Randomized Control Trail	291 preschool children 12 to 60 months

Table 4. The result of the quality assessment appraisal by two reviewers

Items	Jacobs *et al.*[62]	Kopycka *et al.*[57]	Kopycka *et al.*[77]	Estai, *et al.*[76]	Namakian, *et al.*[33]	Morosini *et al.*[59]	Amavel *et al.*[61]	Brullman *et al.*[79]	Mandal *et al.*[78]
1	N	Y	N	N	N	N	N	N	Y
2	UC	Y	N	Y	Y	Y	Y	Y	UC
3	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Y	Y	Y	Y	Y	Y	Y	Y	Y
5	Y	Y	Y	Y	Y	Y	Y	Y	Y
6	Y	Y	Y	Y	Y	Y	Y	Y	Y
7	Y	Y	Y	Y	Y	Y	Y	Y	Y
8	Y	Y	Y	Y	Y	Y	Y	Y	UC
9	Y	Y	Y	Y	UC	Y	UC	Y	UC
10	Y	Y	Y	Y	Y	Y	Y	Y	Y
11	Y	Y	Y	Y	N	Y	Y	Y	Y
12	Y	UC	UC	UC	N	UC	UC	N	Y
13	UC	Y	Y	Y	Y	Y	Y	UC	Y
14	Y	Y	Y	Y	UC	Y	UC	UC	Y
Total	**11/14**	**13/14**	**11/14**	**12/14**	**9/14**	**12/14**	**10/14**	**10/14**	**11/14**

Y: Yes, N: No, UN: Unclear.

Table 5. Summary of the statistical analysis of the included studies in the systematic review

Studies	Sensitivity	Specificity	Kappa	PPV	NPV	Accuracy
Jacobs *et al*.[62]	25-100%	68-100%				
Estai, *et al*.[76]	60-62%	97-98%	57-61%	57-66%	97-98%	95-96%
Morosini *et al*.[59]	48-73%	97-98%	78 – 86%	83-89%	96-97%	93-95%
Kopycka *et al*.[77]	100%	81%	61%			
Amavel *et al*.[61]	94-100%	52-100%		67-100%	94-100%	
Mandal *et al*.[78]	80%	73%	46%	92%	50%	
Namakian, *et al*.[33]	81.3-87.5%	81.6-94.7%	50 – 80%	87.9- 94.7	65.0 -87.5%	
Brullman *et al*.[79]	73-100%					87-92%
Kopycka *et al*.[57]			87-93			

PPV: Positive predictive value, NPV: Negative productive value.

Figure 2. PRISMA flowchart of included studies in the systematic review

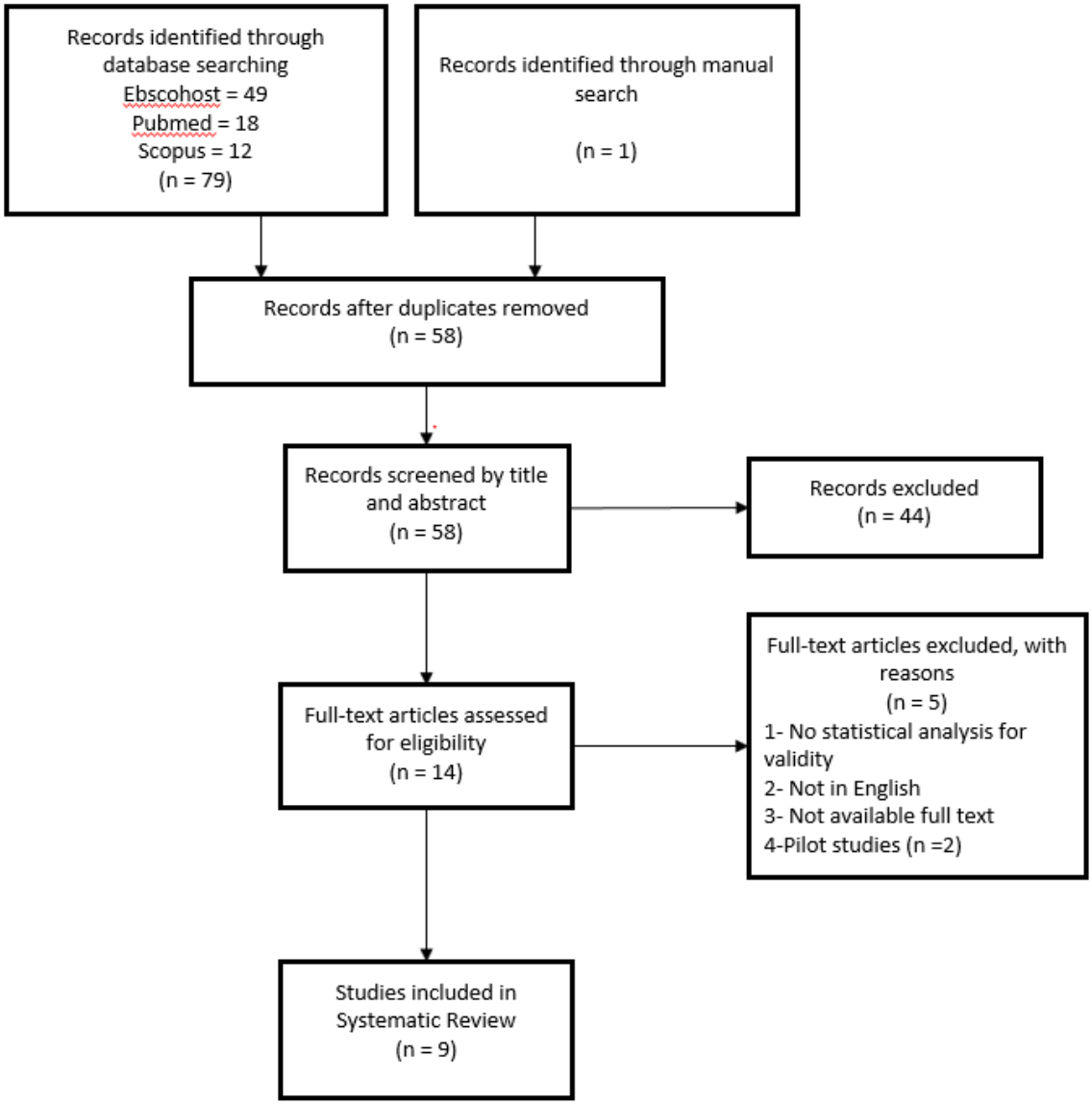


Figure 3. The item lists of the quality assessment of studies of diagnostic accuracy (QUADAS) appraisal tool.[55]

Item	Description
1	Patients representation
2	Clear selection criteria
3	Reference standard classify the target condition
4	Enough time between reference standard and test
5	Sample receive verification using a reference standard
6	Patients receive the same reference standard
7	Independent Reference standard
8	Index test described in detail
9	Reference standard described in detail
10	Results interpreted without knowledge of reference standard
11	Reference standard results interpreted without knowledge of index test
12	Clinical data available
13	Uninterpretable/ intermediate results reported
14	Withdrawals explained

CHAPTER III

PROJECT II: THE ASSOCIATION OF DEMOGRAPHIC FACTORS, INDIVIDUAL CHARACTERISTICS, AND PREVIOUS EXPERIENCE WITH DENTAL STUDENTS' INTENTION TO USE TELEDENTISTRY

Introduction

The shortage of U.S. dental professionals, specifically dentists continues to be a concern in accessing dental services, which impacts the burden of dental diseases.[24,25] People who live in rural areas find it difficult to access dental care and dental care specialists.[26] There are more than 57 million individuals in the U.S. who live in dental health professional shortage areas.[27] There is 70% unmet need for dental professionals in rural areas, which limits access to individuals with considerable dental care needs.[27,29] The U.S. is in need of at least 9,951 dental practitioners in underserved areas to overcome barriers to accessing oral care.[27] Thus, identifying innovative technology such as telehealth/teledentistry to facilitate communication between dental professionals and patients would likely improve access to oral health care.

The application of information and communication technology (ICT) in healthcare, such as telehealth and telecommunication, is a new approach for delivering oral care and facilitating consultations between dental professionals.[20] Telemedicine or teledentistry is the use of information communication technology and dental expertise to enable distance diagnosis and consultation with patients and dental specialists.[16] Teledentistry allows dental professionals to make decisions about treatment without physically meeting patients.[33]

The benefits of a teledentistry system have been established in previous studies.[33,59,61] Teledentistry is a valid method for providing dental examinations. Studies have shown that there

is no difference between visual examinations or distance teledentistry examinations.[48,80] In addition, teledentistry can be a helpful tool for interprofessional communications and for use in dental education.[81] Unfortunately, the adoption of teledentistry in U.S. dental practices is still limited.[20]

Dental professionals' knowledge and acceptance of IT is a critical factor in the successful implementation of this new dental care modality. The use of technological interventions cannot be achieved if health professionals such as dentists are unwilling to use the system.[23,34] Therefore, it is necessary to understand factors associated with future dentists' willingness and readiness to use teledentistry and effectively incorporate it into their future clinical practices. Also, identifying factors related to dental students' intention to use teledentistry is important for planning and curriculum development.

As far as we know, no studies have examined factors such as knowledge, experience, and individual characteristics associated with the intention to use teledentistry among dental students in the U.S. Therefore, it is necessary to conduct a study that would investigate these factors to fill the gap in the literature and to increase knowledge and utilization of teledentistry among future dentists. Thus, the purpose of this study was to expand the knowledge base related to factors such as knowledge, experience, and sociodemographic characteristics of 4th-year predoctoral dental students' intention to use teledentistry in their future clinical practice.

Methods

Study design and population

Permission to conduct the study was obtained from the Human Subject Institutional Review Board (IRB) of the University (IRBNet ID: 1387448-2). A cross-sectional design was

used to describe factors related to the intention to use teledentistry among U.S. fourth-year pre-doctoral dental students in their last semester of dental school. An invitational email was sent to all academic deans of the U.S accredited. dental schools (N=66) listed on the American Dental Association's (ADA) webpage. Dental schools that agreed to participate with no additional IRB approval requirements were included in the study.

Data Collection Procedures

Sixteen academic deans agreed to participate in the study and met the inclusion criteria. The academic Deans were then asked to electronically disseminate the survey through an anonymous link using Qualtrics® software to their dental students. The academic Deans received weekly emails over the course of 4 weeks to remind students to complete the survey. The survey was distributed to the students during spring semester (March-April 2019). To promote completion of the survey and to ensure an adequate response rate, a raffle to win Amazon gift cards was used as an incentive (ten $50 Amazon gift cards). Recipients of the gift cards were chosen through a random process. Confidentiality during gift card distribution was maintained. The survey was disseminated to a total of 1,416 dental students; 210 completed the survey representing a 14.8% response rate (Figure 4). Participation in this study was completely voluntary without any obligations, and participants were assured that their response would be anonymous.

Questionnaire and Instrument

The survey included demographic characteristics (age, gender, race, ethnicity, experience with teledentistry, previous degree, dental institution type, and geographic locations). Students' degree acquired before entering the dental schools and the major area of study was also reported. Participants were asked to report their previous experience with teledentistry, and they were

asked to identify the methods in which teledentistry had been introduced, such as courses lectures, continuing education, clinical experience, and self-study (Appendix A).

The dependent variable was future intention to use teledentistry. Items that measured the dependent variable were derived from Venkatesh *et al.*[38] A five-point Likert scale (1 = strongly disagree, 5 = strongly agree) was used with the higher score indicating a greater intention to use and adopt teledentistry.[82,83] Three-statement items were used to measure the dependent variable such as: *"I intend to use teledentistry in next 6 months"* (Appendix A). Reliability was tested to ensure the outcome items were consistent with one another and to indicate how well they were measured. To ensure clarity of the survey, four research experts reviewed the instrument for content validity and reliability before dissemination from a leading university.

Data Analysis

Statistical Package for the Social Sciences Software (SPSS. Version 21.0) was used to analyze the data. The alpha level was set at 0.05. Cronbach's alpha (α) was used to test reliability for items measuring the BI to use teledentistry. Simple linear regression with dummy coding was used to determine the association between demographic factors and dental student's intention to use teledentistry. The independent *t*-test was used to compare the means of any two independent groups. To test the prediction of the set of variables, multiple linear regression was utilized to test the linear relationship between the dependent variable (BI) and the predictors.

Results

Figure 4 showed that a total of sixteen dental schools participated in the study with a total of 210 completed surveys included in analyses. Table 6 shows the geographic regions of the participated dental schools. Most of the included dental schools (n= 6) were in the Southwest region of the U.S. The complete list of dental schools and class sizes are listed in Appendix B.

Descriptive statistics and demographics

The majority of the participants were female (n = 134, 63.8%) and 36% were male. Participants' mean age was 27.20 years (n = 210, SD = 3.22, Range = 22-49 years) and most of the respondents were between 22 to 30 years old (n = 191) accounting for 90% of the total participants. The majority, of participants were White (58.9%) and Asian (24.7%). In terms of education, (63.5%, n = 155) reported earning a Bachelor of Science (B.S.) degree prior to entering the dental school. Most participants (70%) reported that their schools were in urban areas (n = 174). Also, participants were asked about the geographic locations that were associated with their adolescent-childhood years. Among 210 participants, 54.7% had lived in suburban locations, 23.8% urban areas, and 21.4% in rural areas (Table 7).

Students were asked about their previous experience and knowledge with teledentistry. For the purpose of the analysis, participants were divided into two groups based on their previous exposure and knowledge of teledentistry. The first group included participants with no experience (n = 68) which accounted for 32.4% of participants. The second group included those who had some knowledge, experience, training, etc. about teledentistry (n= 142), which accounted for 67.6 % of participants (Graph 1). In addition, those who had experience were asked to report their source of exposure and knowledge of teledentistry. Part of the participants (50%) reported that they attended course lectures about teledentistry (Graph 2).

The dependent variable and analyses

The behavioral intention measurement was obtained from three survey items (Table 8). The mean of the BI was 2.87 (SD = 10.1). The BI reported excellent reliability ($\alpha > 0.90$).

The regression findings revealed that there was no statistically significant relationship with participants' age, gender, race, and ethnicity and their BI to use teledentistry (F (1, 208) =

0.02, $p = 0.896$. $R^2 = 0.00$, F (1, 208) = 2.76, $p = 0.098$, $R^2 = 0.013$, F (4, 205) = 0.71, $p = 0.585$, $R^2 = 0.014$, F (1, 208) = 0.92, $p = 0.340$, $R^2 = 0.004$, respectively). In addition, there was no significant association with institution type (public vs. private) and types of degrees earned before dental schools with the BI to use teledentistry (F (1, 208) = 3.7, $p = 0.057$, $R^2 = 0.017$, F (6, 203) = 0.37, $p = 0.897$, $R^2 = 0.01$, respectively). Thus, all these factors were not predictors of BI to use teledentistry among dental students.

We assumed participants lived in rural areas prior to enrolling in dental schools would be more likely to use teledentistry than those living in urban or suburban areas. However, there was no statistically significant association with living in rural areas and the BI to use teledentistry (F (2, 207) = 1.47, $p = 0.233$, $R^2 = 0.014$).

Participants who had teledentistry experience were anticipated to be more likely to use teledentistry compared to those who had no experience. Testing results supported a significant positive ($r = 0.22$) association of prior teledentistry exposure on the BI to use teledentistry (F (1, 208) = 10.35, $p < 0.01$, $R^2 = 0.05$). Moreover, to determine whether participants had been exposed to teledentistry or telehealth, they were asked if they had been patients when telehealth or teledentistry was used for any dental or medical purposes. Only 21.4% of the respondents had ever been a patient when teledentistry or telehealth technology was utilized (Table 7). The results showed that the BI to use teledentistry was significantly higher among those who had been exposed to telehealth as a patient (t (208) = 3.6, $p < 0.01$).

To test the extent of the previous exposure of teledentistry in predicting the BI over and beyond the demographic variables, hierarchical multiple regression was performed to investigate the overall correlation in the model in predicting the outcome. The first step included

demographic variables and the second included previous exposure to teledentistry (exposure in dental schools, or as a patient).

Results showed that the overall model after controlling for the demographic variables was positively significant in predicting the BI to use teledentistry (F (8, 201) = 4.40, $p < 0.01$, R^2 = 0.15). The independent variables combined were able to explain 15% of the variance in the dependent variable (BI). The teledentistry exposure beyond the demographic factors significantly explained an additional 10% of the variance in the BI of using teledentistry (R^2-change = 0.10).

The full model showed that school type, adolescent-childhood location of participants, exposure to teledentistry as a patient and previous experience with teledentistry added statistical significance to the prediction of the model (Table 9). In the model, the *B* coefficient of the exposing to telehealth as a patient was negative indicating the contrary results of the bivariate analysis. A possible explanation is that there were not enough variations in the variable as only 21% of the participants were exposed to telehealth as a patient. Another explanation is that possible multicollinearity exists between the "exposing to telehealth as a patient" variable and other variables. Further analysis was conducted to test the model after removing the "exposure to telehealth as a patient" variable from the model. The results showed that the model still significantly predicting the outcome and were able to explain 12% of the variance of the BI (F (7,202) = 3.92, $p < 0.01$, $R^2 = 0.12$).

Discussion

Due to the limited application and utilization of telehealth in dental practices, there is a need to investigate factors that could be associated with the future implementation of this technology. Dental students who soon will be dental care providers are an ideal population to

study perceptions and factors related to their intention to use teledentistry in order to predict the future use of this technology. Moreover, knowledge and perceptions of dental students about teledentistry would reflect the depth of their institution's curriculum contents regarding teledentistry. Thus, this study was conducted to investigate individual factors and previous exposure to telehealth/ teledentistry associated with 4th-year dental students' future intention to use teledentistry.

Findings from this study showed that dental students reported lower intention to use teledentistry in general. The mean of their BI to use teledentistry in their future practice was 2.87. This means participants mainly tend to disagree or strongly disagree with the statements in Table 8 that measure their intention to use teledentistry in the future. These findings were in line with previous research that found health care professionals typically express lower intention toward technological interventions.[84] Therefore, these findings lead to future investigations to explore other factors that may be related to intention to use teledentistry.

The present study findings did not reveal a significant association between dental students' demographic factors and intention to use teledentistry. However, some studies have found age and gender to be associated with acceptance and adoption behavior when implementing new technological innovations,[85,86] In terms of age, younger users were found to be more likely to implement new technological innovations than older users.[84,87] Male primary care physicians were found to be significantly more likely to use computers and electronic health records (EHR) compare to female physicians.[87] However, the present study is consistent with some previous studies that found age and gender not to be significant predictors of dental students' intention to utilize teledentistry.[88,89,37] This could be due to the homogenous nature of the demographics in the present study; for example, the majority of the participants were aged

22-30 years, female, and non-Hispanic. The fact that the participants were from one level (4th year), they shared common individual characteristics which might help to control the influence of demographic variables among groups; therefore, no significant association was found with the demographic factors and the outcome in the study's sample.

The present study supports previous evidence on prior experience as a key predictor of the BI. Health professionals with prior experience with e-health interventions were more likely to accept new innovations.[84,90] Individuals' attitude toward technological intervention is influenced by previous experience and education.[91,92] Exposure to teledentistry in dental schools was directly correlated to the dental student's BI to use teledentistry in practice; therefore, exposure to teledentistry in school may be a predictor for dental students' acceptance and willingness to integrate teledentistry in clinical practice. It is well known that perceptions and attitudes toward technological innovations change by gaining more knowledge and experience.[91] If dental students are exposed to didactic and clinical experiences related to teledentistry during their professional programs, they may be more likely to use it in the future. Education and exposure should be considered as factors to change dental students' attitudes and behavior toward teledentistry and thereafter, improve the future acceptance of this technology.

The commission on dental accreditation (CODA) did not clearly state using teledentistry in dental school as a mandatory standard for accreditation. However, they required application of technologies in the educational environment.[93] Graduates from dental schools should be able to apply emerging science and technology in their clinical practice. Dental institutions must have a curriculum plan that incorporates clinical and didactic technologies to support the education program in dental schools.[93] In addition, the CODA standards for patient care CODA emphasizes

the use of evidence to assess new technologies that would help in diagnosis and treatment decisions.

The commission on dental accreditation recommends that dental institutions use technologies for dental education since it has the potential to decrease teaching expenses.[93] The commission on dental accreditation standard related to technology mainly focuses on the use of technology for dental education to support asynchronous and distance learning. Thus, when dental students receive experience with teledentistry in dental schools, they become more adept and willing to use teledentistry in their future. This concept is in alignment with Cilliers *et al.*[94] who found that previous experiences were the second largest predictor of students' BI to use mobile phones to search for health information.

Interestingly, it seems that dental students did not receive enough education regarding the use of teledentistry technology in their schools. Only 23% of dental students stated they had clinical experience and 50% attended lectures about teledentistry (Graph 2). These findings explained the low intention among dental students to use teledentistry as it has been suggested, the more education about IT, the greater exposure may create a positive perception toward IT innovations.[95] Hands-on experience with a technological system is hypothesized to be a factor associated with the formation of perception that determines BI. With limited experience with a system, individuals' BI would not be expected to be well-formed and stable.[96]

In line with this study, Steininger and Stiglbauer[90] used a nationwide survey to find factors that impacted Austrian general practitioners' intention and acceptance to use electronic health records (EHR). The study found that experience with health information technology significantly related to a positive perception of EHR, which in turn had an impact on physicians' intention to use the EHR system. Moreover, the current study found that dental students who had

been patients when teledentistry or telehealth was used reported significantly higher intention to use teledentistry. Therefore, these findings suggest that not only previous experience but also familiarity with the telehealth system may foster dental students' intention to use teledentistry.

Furthermore, the model showed that demographic variables and previous exposure to teledentistry significantly predicted the 4th-year dental students' intention to use teledentistry. The demographic factors explained only 5% of the variance in the BI but after adding exposure to teledentistry factors, the model explained 10% of the outcome variance above and beyond the demographic variables, indicating the importance of the prior experience on the behavioral intention. However, in the model and after accounting for the demographic factors in the first block, the exposing to telehealth as a patient showed a negative association with the behavioral intention. Therefore, further studies should investigate if exposure to telehealth as a patient could increase the likelihood of dental professional use of telehealth or teledentistry in the future. Future research should focus on factors other than demographics such as dental school curricular content that may influence the future implementation of teledentistry.

Several limitations were associated with this study. First, the generalizability of results was limited due to possible selection bias where the participants had their own decision to participate. After sending an invitation to all U.S. dental schools, only 16 dental schools met the inclusion criteria and agreed to participate. Moreover, in some states, the use of teledentistry is not legal and may limit the interest of dental schools to teach teledentistry. Self-reporting and recall bias are also limitations to consider based on the data collection method. Lastly, due to the cross-sectional nature of the study, findings only applied to the time during which the study was conducted and cannot be applied to future students. Further research should consider a

longitudinal study that investigates other barriers such as curriculum content related to dental students' future utilization of teledentistry.

Further, this study has educational and practice implications. Additional research is needed that examines the comparison of dental professionals currently using teledentistry and experiences to professionals that do not use teledentistry and identify reasons for non-use. Future research should also identify dental education schools/colleges that teach teledentistry and use technology in clinical care. Moreover, research should consider identifying dental and allied dental professionals in clinical practices (private or public health settings) that use teledentistry to determine benefits and costs. Further research is needed to identify a viable method to obtain input from teledentistry patients regarding the satisfaction and benefits of the technology and subsequent care.

Conclusions

The present study is the first to investigate factors related to dental students' intention to use teledentistry. Dental students are future dental care providers; therefore, they are the main element in the adoption and implementation of teledentistry in clinical practice. Findings from this study will assist in understanding the barriers associated with the adoption of teledentistry and facilitate starting points to integrate teledentistry into dental education. Even though there is growing evidence on the validity and efficacy of teledentistry, studies that have investigated barriers to implementation are limited. Previous exposure to teledentistry seems to have a greater association on the dental students' intention to use teledentistry than other individual factors. It is incumbent upon dental institutions to consider the importance of teledentistry in oral care and incorporate the use of this technology in the educational curriculum.

Table 6. Geographic regions of dental schools and access population by region

Geographic Regions	# Participating Schools	Access Population
West	3	205
Southwest	2	200
Midwest	2	253
Southeast	6	398
Northeast	3	360
Total	**16**	**1,416**

Table 7. Dental students sample demographics and characteristics

Demographics Characteristics	Frequency	Percentage %	P-Value
Gender			
Male	76	36.19	0.098
Female	134	63.81	
Age			
22-30	191	90	
31-40	16	7.6	0.896
40-50	3	1.4	
Race			
American Indian/Alaskan Native	3	1.4	
Asian	53	24.7	
Black/African American	15	7	0.585
Native Hawaiian/ Pacific Islander	0	0	
White	126	58.9	
Other	17	7.9	
Ethnicity			
Hispanic or Latino	28	13.3	0.340
Not Hispanic or Latino	182	86.7	
Degrees before dental school			
B.A.	49	20	
B.S.	155	63.5	
M.A	4	1.64	0.897
M.S.	16	6.6	
Ed.D.	1	0.41	
Ph.D.	2	0.82	
Other	17	7	
School type			
Public	181	86.2	0.057
Private	29	13.8	
School geographic area			
Urban	174	70	
Suburban	57	27.1	0.981
Rural	6	2.9	

Table 7. Continued

Demographics Characteristics	Frequency	Percentage %	P-Value
Adolescent- childhood geographic areas			
Urban	50	23.8	0.233
Suburban	115	54.8	
Rural	45	21.4	
Exposure to telehealth as a patient			
Yes	45	21.4	< 0.001*
No	165	78.6	

Table 8. Descriptive statistics of the outcome (BI)

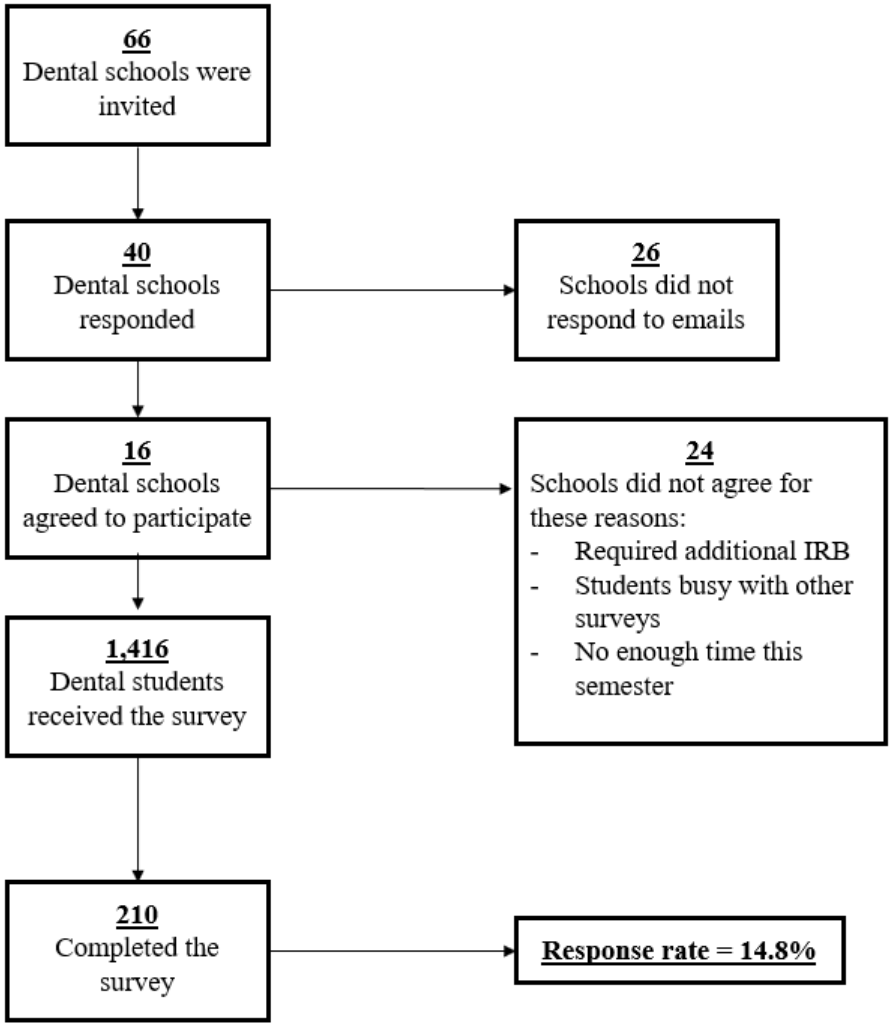
Behavioral Intention items	Mean	SD	Cronbach's (α)
"I intend to use teledentistry in next 6 months"	2.89	1.05	.96
"I plan to use teledentistry in the next 6 months"	2.85	1.03	
"I predict I will use teledentistry in the next 6 months".	2.89	1.06	
	2.87	**1.05**	

Table 9. The full model of all predictors from the multiple regression analysis

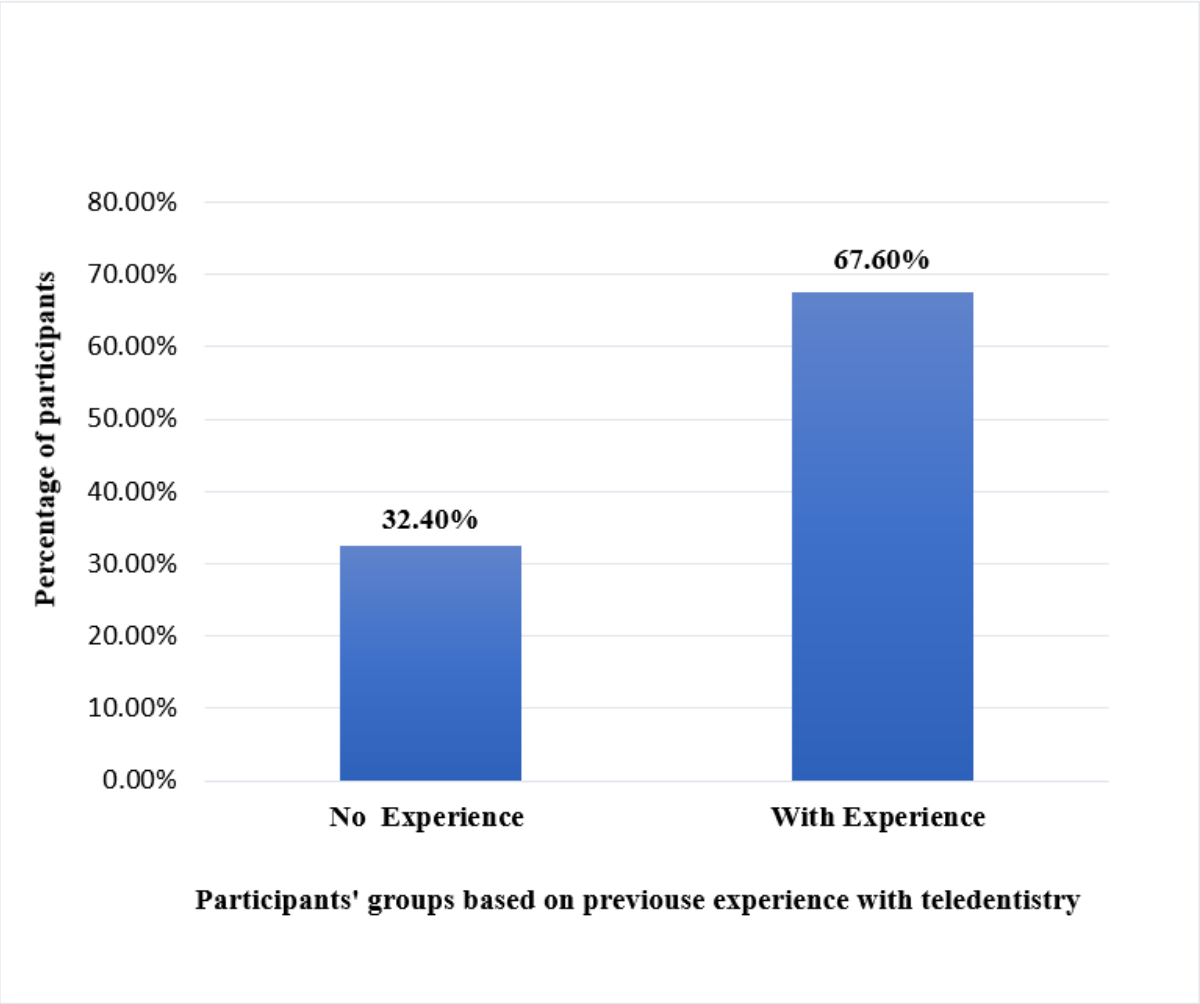
Predictors	*B*	Std. Error	Beta	*t*	*P*
Age	.012	.022	.037	.529	.597
Gender	.220	.140	.105	1.571	.118
Ethnicity	.298	.198	.100	1.510	.133
School type	-.519	.205	-.177	-2.530	.012*
Adolescent-childhood geographic area	-.217	.101	-.144	-2.159	.032*
School geographic area	.079	.129	.041	.611	.542
Exposing to telehealth as patient	-.439	.167	-.178	-2.632	.009**
Experience with teledentistry	.470	.146	.218	3.211	.002**

Dependent Variable: Behavioral Intention

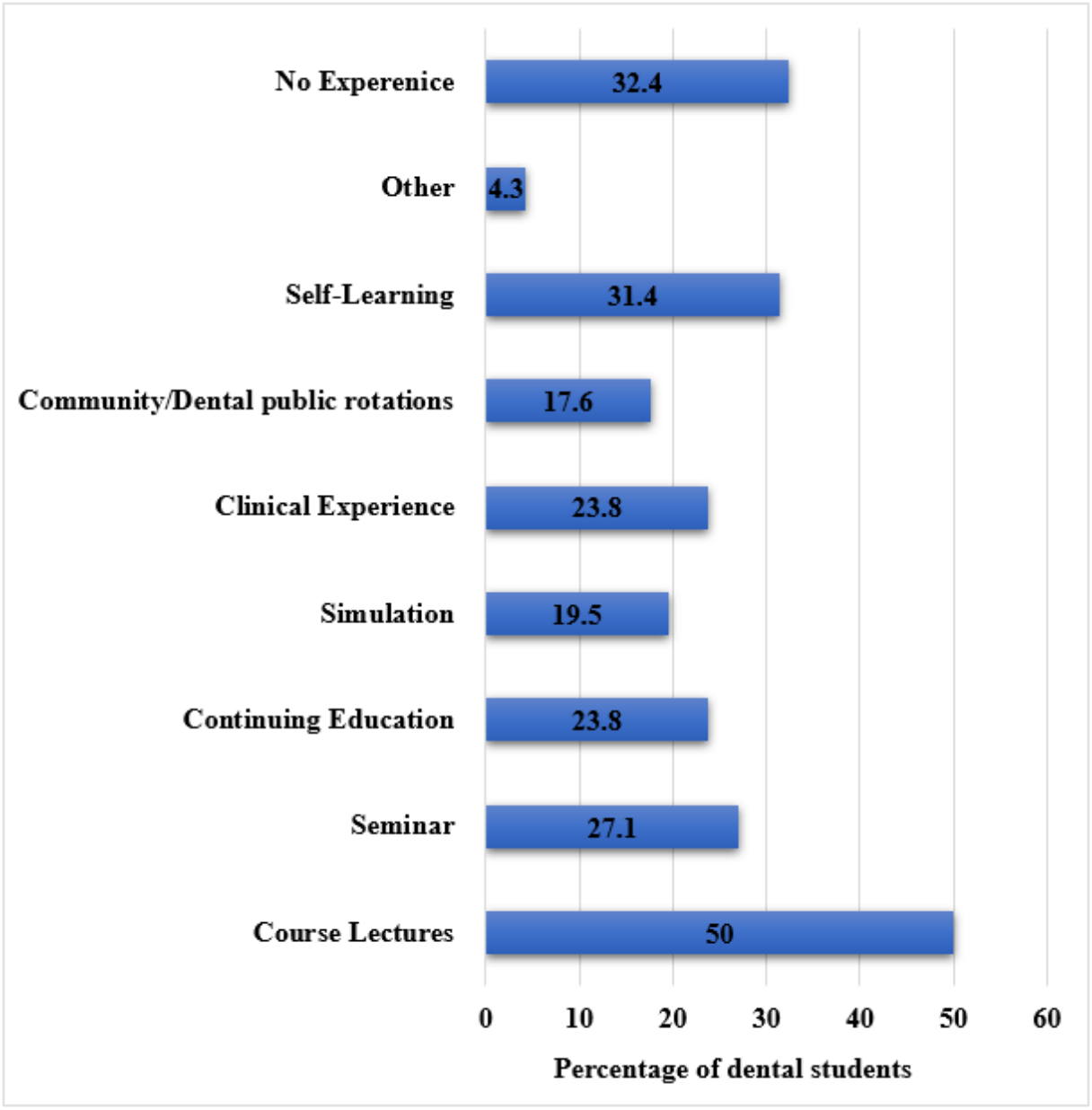
Figure 4. Recruitment process for included schools and sample size



Graph 1. Participants' previous experience with teledentistry



Graph 2. Participants' source of experience or knowledge about teledentistry.



CHAPTER IV

PROJECT III: APPLICATION OF THE UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY MODEL TO PREDICT DENTAL STUDENTS' INTENTION TO USE TELEDENTISTRY[97]

Introduction

The rapid development of information technology offers a new avenue for addressing challenges healthcare systems encounter such as access to healthcare.[1,2] Information technology has been rapidly integrated into healthcare systems to address accessibility and delivery of care challenges to remote communities.[1] Telemedicine- or telehealth- is a good example of using IT for medical and dental services. Telehealth can be broadly defined as the exchange of medical information from one place to another via electronic communication in order to improve health conditions of patients.[4] Telehealth exchanges secure information using applications such as video, smartphones, email, pictures, and any other communication system technologies.[5] Telehealth technology increases access to health services, reduces costs of healthcare treatment, and equipment.[6-8] In addition, telehealth has been found to enhance the quality and efficiency of healthcare services by increasing utilization.[10,64]

The use of telehealth in dentistry is known as teledentistry.[12,64] Today, technology allows dental experts to receive different forms of media, such as dental charts, photographs, radiographs, and written records that allow for consultation with dental specialists.[15,16] Therefore, telehealth in dentistry or teledentistry can be defined as using telecommunication to exchange dental information, images, and video over extensive distances in order to consult with a specialist, either by patients or by other oral care providers.[15,75] Although previous studies have

confirmed the validity and effectiveness of teledentistry for dental diagnosis,[64,76] the adoption of teledentistry is still limited in the U.S. Teledentistry, as a new technological modality, has not been as widely accepted in dentistry as telehealth and telemedicine by medical professionals.[20,21]

User acceptance of IT is a critical factor in the successful implementation of this new healthcare modality.[23] One of the main reasons for the failure of implementation of technology is an insufficient understanding of how individuals accept information technology.[22] Thus, assessment of the association of the social-psychological aspect with the adoption or intention to use a technological system is a key factor.[43] Hu *et al.*[43] found that physicians' acceptance of telemedicine is a very important factor in the implementation and utilization of this technology in the health care system. Thus, understanding factors associated with the acceptance and non-acceptance of telehealth in dental practices could improve access to dental services.

Previous studies have used theoretical frameworks to understand determinants and factors related to users' intention to accept and use technological innovations in the healthcare.[36,40,82] One of the main models utilized to assess individuals' acceptance of a new technological system is the UTAUT presented by Venkatesh (2003).[38] The UTAUT model seeks to explain individuals' intentions to use IT from four main variables which are: performance expectancy, effort expectancy, social influence and facilitating conditions.[38] A study conducted by Sharifian *et al.*[82] utilized the UTAUT model to investigate factors associated to nurses' acceptance of using information systems. The study found that the UTAUT constructs were significantly predicted the nurses' intention to use the hospital information system and the model explained 72.8% of their intentions' variance.[82] Utilizing the UTAUT model to predict BI has been investigated in various settings in healthcare such as telerehabilitation technology,[37] electronic medical record,[41] telemonitoring,[36] eHealth interventions,[84] and telehealth.[98]

To our knowledge, research is not available surrounding the application of a theory-based approach to understand the acceptance and BI of dental students toward the use of teledentistry. An investigation of the factors that predict the acceptance of teledentistry innovation among dental professionals is needed to fill this literature gap. The aim of this study was to use the UTAUT model to predict 4th-year dental students' BI to use teledentistry. We hypothesized that each UTAUT construct and the whole model would significantly predict dental students' BI to use teledentistry.

Materials and Methods

Permission to conduct the study was obtained from the Human Subject Institutional Review Board (IRB) of the University (IRBNet ID: 1387448-2). An observational cross-sectional approach was performed for a seven-week period in the latter part of a traditional spring semester 2019, to study dental students' intention to use teledentistry. The UTAUT model was utilized in order to determine factors associated with fourth-year dental students' intention to use teledentistry in the United States.

Sample

The target population included dental students enrolled in U.S. dental schools. The list of accredited dental schools was obtained from the American Dental Association's webpage (ADA) and all institutions were invited to participate. After sending invitations to the deans of sixty-six U.S. dental schools, sixteen schools agreed to participate. The anonymous questionnaire link was sent to academic deans for dissemination to their 4^{th} year dental students. An electronic survey was developed through Qualtrics® tool and the survey link was distributed to a total of 1,416 dental students. To promote completion of the survey and ensure adequate response rate, 10

Amazon gift cards ($50 each) were raffled as an incentive. After collecting the data and deleting surveys with missing responses, the sample size included a total of 210 dental students representing a 14.8% final response rate (Figure 4).

The Theoretical Framework

The study utilized the UTAUT as a theoretical framework for the research. The UTAUT constructs explained 70% of the outcome variance of behavioral intetnion.[38] The main constructs of the model proposed to predict individuals' BI to use technology, PE, EE, SI and FC that play the role of independent variables (Figure 1). Performance expectancy measures the participants' beliefs in the usefulness and efficiency of teledentistry in the dental field. Effort expectancy measures participants' perception about the difficulty or ease of using teledentistry in dental practice. Social influence measures the participants' beliefs of the impact to significant others such as: colleagues or employers concerning the use of teledentistry. Facilitating conditions measures participants' perception about the availability of enough infrastructure that supports the use of teledentistry (Figure 1).[38]

The dependent variable in the proposed model was BI which would measure participants' intention to use teledentistry in their future dental practice. The intention was used as an outcome instead of the actual use of teledentistry because the application of teledentistry services has not been widely commercialized.[40] Also, participants in this study were dental students who may not have had previous clinical experience with teledentistry. Moreover, previous studies have shown that BI is a good representation of actual behavior.[36,99] Moderating effects of age, gender and experience were not tested in this study.[82]

Based on UTAUT model, this study aimed to test five hypotheses:

- ***H1*:** Performance Expectancy is positively associated with dental students' behavioral intention to use teledentistry.
- ***H2*:** Effort Expectancy is positively associated with dental students' behavioral intention to use teledentistry.
- ***H3*:** Social Influence is positively associated with dental students' behavioral intention to use teledentistry.
- ***H5*:** Facilitating Conditions is positively associated with dental students' behavioral intention to use teledentistry.
- ***H5:*** Overall, the proposed UTAUT model significantly predicts dental students' behavioral intention to use teledentistry.

Questionnaire and Instrument

The questionnaire covered four constructs measuring the UTAUT variables to predict BI. The items of the survey were arranged in the order in which items that measure each construct would be grouped. Participants were asked to report their response to PE (3 items), perception of EE (4 items), perception about SI (3 items), and their belief about FC (4 items). Three-statement items were used to measure the dependent variable (BI) such as *"I intend to use teledentistry in the next 6 months"* (Table 10). Consistent with previous studies, the responses were recorded using a five-point Likert scale (1= strongly disagree to 5 = strongly agree) in which the higher score values would indicate a higher level of a construct, and a higher score of the outcome (BI) indicating greater intention to use teledentistry.[36,82,84]

To ensure the validity of the survey, all questions were adopted with minimum modification from the original instrument developed by Venkatesh *et al*.[38] The original survey also was validated and applied to previous studies based on the UTAUT model.[36-38,84,100,101] The

main modification to the original instrument utilized by Venkatesh *et al.*[38] was changing the word "system" to teledentistry. To ensure clarity of the survey and content validity, research experts reviewed the instrument for content validity, and reliability before dissemination. A panel of four research experts with health services research, telehealth, and dental sciences from the lead institution reviewed the questionnaire.

Data Analysis

Survey data were exported from the Qualtrics online database. For the purpose of analysis, the Statistical Package for the Social Sciences Software (SPSS. Version 21.0) was used. Cronbach's alpha (α) was calculated to test reliability for the items' scales. Reliability was tested to ensure construct items were consistent with one another and to indicate how well the same constructs were measured (Table 10). Simple linear regression was utilized to determine the association between each construct and the outcome. To test the prediction of the whole model, multiple linear regression was utilized to test the linear relationship between the dependent variable (BI) and the set of predictors (UTAUT constructs). The alpha level was set at 0.05 for all analysis. Data preparation and assumption tests are presented in Appendix C.

Results

Descriptive statistics of the UTAUT constructs

Descriptive statistics (mean and standard deviations) were reported to explain and describe the UTAUT constructs (Table 11). The value of each construct ranges from 1 to 5 (1= strongly disagree, 5 = strongly agree). The mean for PE, EE and SI were higher than 3 and the mean for FC was less than 3. The mean of BI was 2.87 which shows a lower level of intention to use teledentistry among the 4th year dental students (Table 11).

Reliability assessment

Cronbach's alpha was used to evaluate the consistency of the UTAUT construct items and to identify how well items correlate with each other (Table 10). A reliability coefficient of 0.70 and above is considered to have an acceptable reliability.[102] Facilitating conditions construct had the lower reliability score; however, it is within the acceptable reliability score (> 0.70). The remaining scales had either good (> 0.80) or excellent (> 0.90) reliability (Table 10).[102] The dependent variable (BI) was obtained from three survey items asking participants to score their responses with statements focusing on their future intent to use teledentistry. The reliability test for the BI was excellent (Cronbach alpha = 0.96).

Hypothesis testing and findings

To test the first four hypotheses, simple linear regression was performed to determine if there was any significant relationship between each UTAUT construct and the dependent variable of BI. The value of Pearson correlation coefficient was reported, and values ranged from -1 to +1 indicating a positive or negative relationship between an independent variable and the outcome.

The results supported the predictive utility of each UTAUT construct for dental students' BI to use teledentistry. The results showed that there was a significant large positive association between PE and dental students' BI to use teledentistry. The largest correlation efficiency corresponded to PE ($r = 0.57$, $p < 0.01$) (Table 12). Performance expectancy explained 33% of the variance in BI to use teledentistry (F (1, 208) = 99.98, $R^2 = 0.33$, $p < 0.01$). Also, the results showed that there was a significant large positive association ($r = 0.49$, $p < 0.01$) between effort expectancy EE and dental students' BI to use teledentistry. Effort expectancy explained 24% of the variance in BI to use teledentistry (F (1, 208) = 66.1, $R^2 = 0.24$, $p < 0.01$). Social influence

showed a significant large positive association ($r = 0.52$, $p < 0.01$) with the dental students' BI to use teledentistry. Social influence explained 27% of the variance in the BI (F (1, 208) = 76.06, $R^2 = 0.27$, $p < 0.01$). Regarding FC, the results indicated that there was a significant medium positive association ($r = 0.38$, $p < 0.01$) between FC and dental students' BI to use teledentistry. Facilitating conditions explained 14% of the variance in the BI to use teledentistry (F (1, 208) = 35.16, $p < 0.01$, $R^2 = 0.15$) (Table 12).

To test the whole model and assess the fifth hypothesis, multiple regression was performed to investigate the overall correlation of the model to predict the outcome. The analysis included all the UTAUT constructs (PE, EE, SI and FC). The behavioral intention was entered in the dependent variable box.

Results testing showed that the overall UTAUT model could predict the BI to use teledentistry F (4, 202) = 32.88, $R^2 = 0.40$, $p < 0$ .01) and supported the fifth hypothesis. Results of the regression indicated that the combined independent variables were able to explain 40% of the variance in the dependent variable (BI) (Table 12).

Discussion

This study was conducted to determine factors associated with 4th year dental students' BI to accept and use teledentistry. All four constructs were found to be good predictors of the acceptance of teledentistry technology, supporting all research hypotheses. Performance expectancy had the strongest correlation, followed by SI then EE and lastly, FC. Those statistically significant relationships indicate the usefulness of the constructs in the UTAUT model. Dental students' BI to use teledentistry is associated with their perception of the benefits of teledentistry to their practice (PE), their perception of ease to use teledentistry (EE), their view

of significant others concerning teledentistry (SI), and their perception of the availability of infrastructures that support the use of teledentistry in dental practice (FC).

Participants tend to agree or strongly agree concerning the importance of the PE in their future intention to use teledentistry. Of the UTAUT constructs, PE was the strongest factor in predicting dental students' BI which explained 33% of the BI variance. These results are consistent with previous studies that found PE as the strongest predictor of the BI to use technological interventions compared to other constructs.[37,82,103] Basically, if dental students believe that teledentistry is going to be advantageous and helpful in their practice, they will be more motivated to use it. Similarly, Alaiad *et al.*[104] found a significant association of PE among patients' adoption behavior of mobile health (M-Health). The UTAUT model was used by Liu *et al.*[37] to examine factors that influence the acceptance and BI by occupational therapists in Canada to use technology for rehabilitation services. They found that PE was the most important predictor for determining occupational therapists' acceptance and use of technologies ($\beta = + 0.585$, $p < 0.01$).[37]

Effort expectancy was directly correlated to BI and could be an ideal predictor for dental students' acceptance and willingness to use teledentistry. If dental students perceive they can use teledentistry easily with minimum effort, they may be more willing to use in practice. This concept is in alignment with Sharifian *et al.*[82] who found that EE ($\beta = 2.21$, $p < 0.01$) was a significant predictor of nurses' BI to use hospital information systems (HISs). Rho *et al.*[40] also found that EE ($\beta = 0.227$, $p < 0.05$) was a significant predictor of participants' intention to utilize telemedicine services. The more effort required when using and implementing technology, the less likely it will be used.[40,41,45] However, a study applied the UTAUT to predict nurses' intention of using an electronic documentation system (EDS) and found that all the UTAUT

constructs were significantly associated with the nurse's BI excluding EE which was not a significant predictor.[105] This finding was also supported by Woo *et al.*[98] who found that EE was not associated with the adoption of telehealth by patients with heart failure. These results suggest participants care mostly about the usefulness of the telehealth system rather than focusing on the ease to use telehealth.

Social influence was significantly associated with BI. Previous studies also found such a relationship based on the UTAUT model.[40,46] Rho *et al.*[40] reported that SI ($\beta = 0.246$, $p < 0.05$) was a significant predictor of diabetic patients' BI to use telemedicine services. Liu *et al.*[46] found that university students' perception of social influence on the use of a physical activity app had a significant prediction on use. This significant relationship between SI and BI was found in several previous studies.[42,104,105] Hence, these findings indicate that dental students believe that employers or other influential peers would be an important factor to their intention to use teledentistry.

Facilitating conditions was a positive significant predictor of dental students' BI to use teledentistry. The association between FC and BI was found to be less predictive ($R^2 = 14\%$) compared to the other UTAUT constructs. The finding suggests that dental students' perception about the availability of teledentistry infrastructure and support is not a strong factor of their future intention to use teledentistry. Yet, facilitating conditions is still a significant factor associated with a professional's BI in the healthcare industry.[106] Our findings were consistent with those of prior studies concerning the technological adoptions in healthcare.[36,106] A study conducted to identify predictors of the intention of healthcare professionals to use a new cloud base health platform (CBHP) technology found FC as a significant factor related to intention to accept and use CBHP.[106] Asua *et al.*[36] identified FC to be the most powerful predictor of medical

professionals' intention to use a telemonitoring system. Therefore, it was concluded that participants are more likely to consider telehealth to be a helpful system if they believe that it has a vigorous infrastructure to support the use of telehealth.[36] Dental students viewed the existence of teledentistry in dental institutions required to support the future use of teledentistry.

The overall proposed model (Figure 1) showed that the 4th year dental students' BI to use teledentistry in their future practice was significantly predicted by all the UTAUT constructs. Performance expectancy, effort expectancy, social influence and facilitating conditions explained 40% of the variance in the BI to use teledentistry. Even though the model was significant in predicting the outcome, the predicted variance (40%) was lower than the original proposed model by Venkatesh *et al.*[38] which was able to predict 70% of the participants BI. Additionally, another study reported that the UTAUT constructs explained 72% of the variance of BI to use hospital information system.[36] A possible explanation for our lower prediction value is that dental students may not have enough knowledge and sophistication of the use of teledentistry. Perhaps teledentistry is not part of the curriculum in U.S. dental schools. Adding teledentistry content to dental curricula is necessary to improve access to care and use in professional dental care. Exposure and experiences to teledentistry while in dental education could increase the likelihood of use in future practice. Our findings suggest that evidence from theory-based research can enhance better understanding of the adoption of teledentistry, which could increase the intention to use teledentistry in dental practice.

One of the main limitations of the study was that teledentistry is considered as an innovative practice in dentistry. Teledentistry may not be introduced or be an integral part of the predoctoral dental curriculum at many dental institutions and consequently, dental students and dentists will not have adequate knowledge or experience using teledentistry. Moreover, the target

population involved only 16 dental schools out of 66 dental schools in the United States limiting external validity. Additionally, actual use of teledentistry was not measured. Instead, the study investigated dental students' future intention to use teledentistry. Finally, the response rate of this study was low which might cause unequal variations among dental students regarding the exposure to teledentistry and limit the generalizability of the study. Given these limitations, this was the first study to use a theoretical framework to predict dental students' future intention to use teledentistry.

Further this study has educational and practice implications. Future research should involve the current users and a comparison with non-users. Also, there is a need to address the acceptance of teledentistry in dental education among dental program directors, their faculty, and among dental professionals who use teledentistry. Furthermore, dental and allied dental professionals who use teledentistry could be studied regarding satisfaction and benefits to patients and professionals.

Conclusions

This study utilized the UTAUT model to add more evidence-based theory to the literature to increase knowledge concerning the use and adoption of teledentistry. The current study provided information about the factors that could be associated with dental students' BI to use teledentistry based on the UTAUT model. Dental school directors and curriculum specialists should consider the aspects of PE, EE, SI, and FC and incorporate these in their teaching and practice of teledentistry to increase utilization. Exposure to the teledentistry in dental schools could increase use among dentists thereby, improving access to acute dental needs. However, due to the small sample size and study's limitations, further studies are needed to establish the association among UTAUT constructs and dental students' BI to use teledentistry.

Table 10. The UTAUT constructs and its measuring scale items

Constructs	Items	Cronbach's (α)
Performance Expectancy (IV)	**PE1:** I would find teledentistry useful in my job. **PE2:** Using teledentistry will enable me to accomplish tasks more quickly. **PE3:** Using teledentistry will increase my productivity.	.85
Effort Expectancy (IV)	**EE1:** My interaction with teledentistry will be clear and understandable. **EE2:** It would be easy for me to become skillful at using teledentistry. **EE3:** I would find teledentistry easy to use. **EE4:** Learning to operate teledentistry is easy for me.	.84
Social Influence (IV)	**SI1:** People who influence my behavior think that I should use teledentistry. **SI2:** People who are important to me think that I should use teledentistry **SI3:** In general, the institution has supported the use of Teledentistry	.86
Facilitating Conditions (IV)	**FC1:** I have the resources necessary to use teledentistry **FC2:** I have the knowledge necessary to use teledentistry **FC3:** Teledentistry is not compatible with other systems I use. **FC4:** A specific person (or group) is available for assistance with the teledentistry difficulties	.71
Behavioral intention (DV)	**BI1:** I intend to use teledentistry in next 6 months. **BI2:** I plan to use teledentistry in the next 6 months. **BI3:** I predict I will use teledentistry in the next 6 months.	.96

PE: Performance expectancy, EE: Effort expectancy, SI: Social influence, FC: Facilitating conditions.

Table 11. Descriptive statistics of the UTAUT constructs

Variable	Mean	SD
Performance Expectancy	3.67	0.71
Effort Expectancy	3.57	.64
Social Influence	3.1	.78
Facilitating Conditions	2.98	.69
Behavioral Intention (DV)	2.87	1.01

DV: Dependent variable.

Table 12. Correlation coefficients between behavioral intention and each UTAUT constructs

Hypotheses	UTAUT	r	R^2	*P*	Hypothesis Results
H1	PE	0.57	33%	**<0.01**	Supported
H2	EE	0.49	24%	**<0.01**	Supported
H3	SI	0.52	27%	**<0.01**	Supported
H4	FC	0.38	14%	**<0.01**	Supported
H5	The Model	0.63	40%	**< 0.01**	Supported

PE: Performance expectancy, EE: Effort expectancy, SI: Social influence, FC: Facilitating conditions. UTAUT: The unified theory of acceptance and use of technology.

CHAPTER V

CONCLUSIONS

The overall purpose of the dissertation was to gain more knowledge about the barriers that might impact future use of teledentistry among dental students. To achieve this purpose, three interrelated studies were conducted. Teledentistry examinations were found to be valid, feasible, and comparable to visual examination for oral screening. Teledentistry may be a comparable tool to use for oral screenings especially for school-based programs, caries assessments, referrals, and teleconsultations. However, there are barriers that could decrease the adoption of teledentistry in dental practices that need to be investigated.

The dissertation is the first to investigate factors related to dental students' BI to use teledentistry. Dental students are future dental care providers; therefore, they are the main element in the adoption and implementation of teledentistry in clinical practice. It is incumbent upon dental institutions to consider the importance of teledentistry in oral care and incorporate the use of this technology in the educational curriculum. Findings from this dissertation assist in understanding the barriers associated with the adoption of teledentistry and facilitate starting points to integrate teledentistry into dental education. Even though there is growing evidence on the validity and efficacy of teledentistry, studies that have investigated barriers to implementation are limited.[20,48]

This dissertation utilized the UTAUT model to add more evidence-based theory to the literature to increase knowledge concerning the use and adoption of teledentistry. The UTAUT model helped to provide information about factors that could be associated with dental students' BI to use teledentistry. Dental school directors and curriculum specialists should consider the aspects of PE, EE, SI, and FC and incorporate these in their teaching and practice of teledentistry

to increase utilization. Exposure to teledentistry in dental schools could increase use among dentists thereby, improving access to acute dental needs. However, due to the small sample size and study limitations, further studies are needed to establish the association among UTAUT constructs and dental students' BI to use teledentistry. Further theory-based research studies are needed to better understand the adoption behavior among dental professionals.

In addition to further exploration on adoption behavior, a review and discussion concerning accreditations standards for U.S. dental schools and teledentistry policies are warranted. The CODA does not require use of teledentistry as a standard for dental programs. However, general application of technologies in the educational environment are required.[93] Graduates from dental schools should be able to apply emerging science and technology in their clinical practice. Dental institutions must have a curriculum plan that incorporates clinical and didactic technologies to support the education program in dental schools.[93] In addition, the CODA standards for patient care emphasize the use of evidence to assess new technologies that would help in diagnosis and treatment decisions. Moreover, in some states, the use of teledentistry is not legal and may limit the interest of dental schools to teach teledentistry. Thus, further research should consider investigating how the states and dental schools' policies might impact the adoption of teledentistry.

Moreover, the main benefits of teledentistry are the cost-saving and increase access to dental care for providers and patients. The cost of teledentistry examinations are found to be lower than in-person examinations in both rural and urban areas.[70] The University of Minnesota established a teledentistry project by linking the dental centers in the university to the remote areas.[11] The teledentistry project saved the patients travel expenses, which would have resulted in 250 miles round trip to the dental center.[11] Moreover, a study by Wood *at al*.[9] aimed to

evaluate telemedicine for oral and maxillofacial consultation over a 6-year period. The amount saved by conducting consultation through the telemedicine system was considerable at $134,640.[9] Further studies should investigate longitudinal cost-effectiveness of teledentistry utilization for dental services. Additionally, teledentistry could provide more value, save time and costs during disease outbreaks and pandemics.

In the current global pandemic outbreak of the Coronavirus disease 2019 (COVID-19), teledentistry can play a pivotal role in providing dental consultations and education to patients with non-urgent needs. Teledentistry can offer an additional protective layer during pandemics by reducing contact among patients and dental staff for non-urgent dental needs. During the COVID-19 pandemic, healthcare systems including dental professions face a higher expenditure to overcome the need for supplies and personal protective equipment (PPE) to control the risk of infection for patients and dental care workers. Thus, awareness among policymakers should arise about considering teledentistry as a standard tool for care during and after pandemics to increase access to patients and reduce operational costs of offices and clinics.

Further this dissertation has educational and practice implications. Additional research is needed that examines the following groups: 1) Comparison of dental professionals currently using teledentistry and experiences to professionals that do not use teledentistry. 2) Identify dental schools that teach teledentistry and use the technology in clinical care. 3) Identify dental hygiene educational programs/ schools that teach teledentistry and apply it in clinical care. 4) Identify dental and allied dental professionals in clinical practices (private or public health settings) that use of teledentistry to determine benefits and costs. 5) Identify a viable method to obtain input from patients who have used teledentistry to gauge their satisfaction and perceived benefits of the technology. Also, future research should consider a longitudinal study that

investigates other barriers such as curriculum content related to dental students' future utilization of teledentistry. Additionally, there is a need to address the acceptance of teledentistry in dental education among dental program directors and their faculty. Furthermore, teledentistry users who use teledentistry could be studied regarding satisfaction and benefits to patients and professionals from the user perspectives.

In addition, further studies should investigate the standardization of cameras, examiners, settings, and type of statistical analyses to facilitate comparisons of teledentistry to in-person examination. Further research is essential to examine the accuracy of using live video in conjunction with photo conferencing for dental diagnosis and consultation. There are limited studies that investigated the use of video conferencing for dental purposes. Still, further investigation is needed to enhance the quality of images to improve the validity of teledentistry as the quality of the images play a vital role in delivering accurate diagnoses. The present dissertation suggests that more investigations are needed to examine the validity of teledentistry using a variety of technology and software platforms within different settings and populations.

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APPENDICES

Appendix A

The Online Survey

Opening Page

The purpose of this questionnaire is to obtain knowledge, perceptions, and intention of 4th year pre-doctoral dental students' application of telehealth in dental practices (Teledentistry) in order to determine future utilization of the technology in their dental practices.

Definition of telehealth in dental practice (Teledentistry):

Teledentistry/telehealth is a combination of telecommunication technology and dentistry involving the exchange of clinical information, electronic medical records, videos, images, and radiographs over remote distances for dental consultation and treatment planning (1). An example of telehealth in dentistry is using an intraoral camera to take images of a lesion and sending it to a specialist for consultation.

Note: this survey will use the term "Teledentistry" which refers to the use of telehealth in dental practice.

Please answer the following questions (it should only take 5 – 7 minutes)

Part: 1 Demographic characteristics

1- **Age**

_____

2- **Gender:**
- Male
- Female
- Prefer not to answer

3- **Ethnicity:**
- American Indian/Alaska Native
- Asian
- Black/African American
- Native Hawaiian/ pacific Islander
- White
- Other

4- **Select the degrees you acquired before entering dental school. Please indicate the major area of study.**
- B.A. _____
- B.S._____
- M.A._____
- M.S. _____

- Ed.D._____
- Ph.D._____
- Other_____

5- Your current dental institution is:
- Public
- Private

6- The geographic area of your dental institution is:
- Urban (>3,000 people per square mile)
- Suburban (1,000 – 3,000 people per square mile)
- Rural (<1,000 people per square mile)

7- Select all of the following methods in which you have been introduced to telehealth for oral care (teledentistry).
- Course Lectures
- Seminar
- Continuing Education
- Simulation
- Clinical Experience in the dental school
- Community/Public dental health rotation
- Self-learning (reading in journal articles, textbooks. etc.)
- Other
- No previous experience

8- Have you ever been a patient when telehealth techniques were used either in dentistry or healthcare?
- Yes
- No

Part 2: The participants' perceptions of telehealth applications for oral care (teledentistry).

In the next section, please answer the questions based on your perceptions as it relates to your future telehealth application in dental practice.

To what extent do you agree with the following statements? Please select one of the following answers (*Strongly disagree, Disagree, Neutral, Agree, Strongly disagree)*

Construct	#	Item	SA	D	N	A	SD
Performance Expectancy	9	I would find teledentistry useful in my job.					
	10	Using teledentistry will enable me to accomplish tasks more quickly					
	11	Using teledentistry will increase my productivity					

Effort Expectancy	12	My interaction with teledentistry will be clear and understandable
	13	It would be easy for me to become skillful at using teledentistry
	14	I would find teledentistry easy to use
	15	Learning to operate teledentistry is easy for me
Social Influence	16	People who influence my behavior think that I should use teledentistry.
	17	People who are important to me think that I should use teledentistry
	18	In general, the institution has supported the use of teledentistry
Facilitating Conditions	21	I have the resources necessary to use teledentistry
	22	I have the knowledge necessary to use teledentistry
	23	Teledentistry is not compatible with other systems I use.
	24	A specific person (or group) is available for assistance with the teledentistry difficulties.

Please answer the following questions as if you have taken your first position.

Construct	**#**	**Item**	SA	D	N	A	SD
Behavioral Intention (DV)	25	I intend to use teledentistry in next 6 months					
	26	I plan to use teledentistry in the next 6 months					
	27	I predict I will use teledentistry in the next 6 months.					

Appendix B

Participating dental school list and class size

#	Dental School Name	States	Class Size
1	University of Kentucky College of Dentistry	KY	58
2	University of Detroit Mercy School of Dentistry	MI	144
3	Tufts University School of Dental Medicine	MA	230
4	Western University of Health Sciences College of Dental Medicine	CA	68
5	University of Tennessee College of Dentistry	TN	100
6	University of Utah School of Dentistry	UT	27
7	Texas A&M University College of Dentistry	TX	100
8	The University of Texas School of Dentistry at Houston	TX	100
9	University of Pittsburgh School of Dental Medicine	PA	85
10	West Virginia University School of Dentistry	WV	46
11	University of California at San Francisco School of Dentistry	CA	110
12	University of North Carolina at Chapel Hill School of Dentistry	NC	84
13	East Carolina University School of Dental Medicine	NC	50
14	University of Missouri Kansas City School of Dentistry	MO	109
15	Meharry Medical College School of Dentistry	TN	60
16	Stony Brook University School of Dental Medicine	NY	45

Appendix C

Assumptions Testing and Data Preparation

For all the data analysis, the confidence level was established at 95% and alpha was set at 0.05. Before conducting the analysis, data were assessed to make sure it did not violate the assumptions for the regression analysis (multiple regression and linear regression). The assumptions included Normality, Linearity, Outliers, Homoscedasticity, Independence and Multicollinearity. The data were tested for normality utilizing the Z-test using kurtosis and skewness. The Z score is calculated by dividing skewness or kurtosis value by their standard errors. For the medium sample size ($50< n <300$), the Z score should be between $\pm$ 3.92, and alpha level at .05 to fail to reject the null hypothesis of normality and conclude the sample is normally distributed. Most of the variables have Z scores lower than 3.29 and were normally distributed. To check the linearity between the predictor variables and the outcome, a scatterplot using SPSS was checked for each predictor and the outcome. The scatterplot charts should show linear trend between independent variables and the outcome. Homoscedasticity was assessed using the scatterplot of the unstandardized predicted value against standardized deleted residuals. Predictors residual should not make a trend, decrease, or increase across the predicted outcome to meet the assumption. Only one predictor (age) violated the homoscedasticity assumption. To check the observation independence assumption, the Durbin-Watson statistic test was used, and the test results range from 0 to 4 where a score of 2 indicates variable independency with no autocorrelation between residuals. Durbin-Watson values in the range of 1.5 to 2.5 are considered normal, all the variable values were in the normal range. The variance Inflation Factor (VIF) was utilized to test the multicollinearity assumptions for the multiple regression model. All the VIF values were less than 10 which indicates no concern about multicollinearity.

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Alabdullah, J. H., Van Lunen, B. L., Claiborne, D. M., Daniel, S. J., Yen, C. J., & Gustin, T. S. (2020) Application of the unified theory of acceptance and use of technology model to predict dental students' behavioral intention to use teledentistry. *Journal of Dental Education*, (7),1-8. https://doi.org/10.1002/jdd.12304

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