Systematic Review

Evidence based teledentistry: a systematic review of literature on smartphone apps

Shubham Datta[1], Panchali Batra[2], Uqba Raza[1], Shubhangi Premchandani[1], Deborah Sybil[3]*

[1]Jamia Millia Islamia, New Delhi, India
[2]Department of Orthodontics and Dentofacial Orthopaedics, Jamia Millia Islamia, New Delhi, India
[3]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India

*Correspondence:
Dr. Deborah Sybil,
E-mail: dsybilg@gmail.com

ABSTRACT

Dental healthcare continues to be limited for large populations of both developing and developed nations. Hectic metropolitan work schedule, improper dentist-population ratio, lack of awareness, or global health emergencies such as the ongoing COVID-19 pandemic could be the possible reasons. This results in proliferation of teledentistry based practice, aided by global smartphone networking. Smartphone teledentistry apps require proper scientific literature backup along with ready availability in popular app stores such as Google Play store, and Apple app store. This article aims to identify which smartphone apps designed to provide teledentistry features are rooted in evidence-based literature such that the percentage of scientifically supported apps that were commercially available to consumers can be determined. Smartphone apps for teledentistry were evaluated in three phases. Phase 1 identified all teledentistry apps reported in the scientific literature. Phase 2 identified which apps from the literature review were available in the app stores. Phase 3 identified the top teledentistry apps available in the app stores. 11 studies identified 5 apps with only 1 being available in both the app stores. Few apps qualified the scientific searching process, whereas the number of apps available on app stores are greater.

Keywords: Smartphone apps, Teledentistry, Literature evaluation, Dental care

INTRODUCTION

Despite great improvement in oral health, WHO data reveals that some underprivileged groups in both developed and developing communities, suffer from oral diseases and conditions including dental caries, periodontal problems, oral cancer, oral manifestations of HIV/AIDS, dental trauma, craniofacial anomalies and noma (cancrum oris), all of which have broad impacts on health and well-being. WHO states that 80% of the global population suffering from oral diseases live in developing countries.

Globally, approximately 2.3 billion people suffer from permanent teeth caries and more than 530 million children suffer from those of primary teeth. There are an estimated 657,000 new cases of cancers of the oral cavity and pharynx each year, and more than 330,000 deaths.[1]

Even a large population of developed nations lack proper dental care probably due to insufficient dental care providers, lack of insurance, prohibitive cost or mobility issues. Busy lifestyle, lack of awareness and proper counselling and improper dentist-population ratio are also some of the contributing factors. With hectic metropolitan work schedule, people tend to neglect dental health until some serious issue occurs.

Several surveys indicate that access to primary oral health services ranges from 35% in low-income countries to 60%

in lower-middle-income countries, 75% in upper-middle income countries and 82% in high-income countries. In high income settings, dental treatment estimates to about 5% of total health expenditure and 20% of out-of-pocket health expenditure.[23]

Moreover, the COVID-19 pandemic has also restricted dental practice to a great level. The SARS-CoV-2 virus (responsible for the pandemic) is said to spread from person to person with increased risk of spread when people are in proximity (within 6 feet) through respiratory droplets generated by infected, symptomatic or asymptomatic persons during activities like talking, coughing or sneezing. It is well known that all dental procedures require close contact with patient's oral cavity, saliva, blood, and respiratory tract secretions, putting dentists, auxiliaries and patients at high risk of cross-infection. In such a scenario, dental care has been restricted to treatment of urgent and emergent cases, with many dentists temporarily shutting their practices.

It is here when teledentistry comes to play. Teledentistry, is a combination of telecommunications and dentistry, involving the exchange of clinical information and images over remote distances for education, consultation and treatment planning.[4,5] Teledentistry, in the form of downloadable smartphone applications can play an important role in uplifting dental healthcare.

The steady proliferation of smartphone users globally should be utilized for providing online dental consultations. More than 4.57 billion people around the world now use the internet- close to 60 percent of the world's total population, with most internet users (91 percent) using mobile devices to go online.[6] With use of smartphone applications it could be possible for patients to consult dentists online, amidst busy life schedule, or a healthemergency like the COVID-19 pandemic, which restricts population movement, to curb its spread. Also, it could be possible for dental practitioners, to consult patients online, and only those in need of any procedural treatment be called to the dental clinics, thus providing better triaging and screening facilities.

Such an important annal of dentistry, requires proper scientific literature backup along with ready availability in popular app stores such as Google Play store, and Apple App store. Apps available in the app stores, if properly rooted in the evidence-based literature, provide not only to the patients but also the dental practitioners with a better understanding of their functionality, features, pros and cons. With health app becoming a supplement to modern day healthcare, even within populations who may not have otherwise sought treatment for their conditions, it is vital for researchers to examine the quality and effectiveness of the apps that are available.

However, literature based on teledentistry apps is limited, even in eminent databases like PubMed. This systematic review, identifies the teledentistry apps that are available on popular app stores like Google Play store, and Apple App store, and are supported in evidence-based literature published in PubMed database.

Aim and objectives

The aim and objective of the study was to determine which apps designed to provide teledentistry features are rooted in evidence-based literature and to examine the relation between the scientific evidence and available commercial mobile phone health apps for teledentistry to identify the percentage of scientifically supported apps that were commercially available to consumers.

To achieve this, the app market was examined from two outlooks: the dentalcare provider and the consumer. It is more likely for the dentalcare providers to review the scientific literature to identify apps with scientific background as most consumers are not familiar with the literature. As a result, consumers tend to rely upon the recommendations of online app stores when making dental consultation app selections. Analysis from this dual perspective required a review of the apps from two separate points (1) starting from the literature and finding the identified apps in the stores and (2) starting from the app stores and finding scientific literatures supporting the available apps.

METHODS

To remain consistent with other published systematic reviews of health-related apps the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model, an evidence-based set of criteria for reporting in systematic reviews and meta-analyses, was followed. The PICO analysis of the review question was done which is as follows-

Peoples

Patients seeking dental consultation that does not require invasive treatment, well-oriented with the smartphone apps, or have a caregiver who is well-oriented with the apps.

Interventions

Teledentistry based clinical practice.

Comparison

Conventional clinical practice was carried.

Outcomes

Ability of teledentistry smartphone apps in diagnosing routine as well as complex oral lesions, orthodontic assessments, and patient acceptance towards such technological interventions. For this review, only published research articles related to an app were considered evidence of scientific support. Apps for teledentistry were identified and evaluated for scientific

support in four phases.

Phase 1

Identified all teledentistry apps reported in the scientific literature

Data sources and searches of literature search was conducted during 1st August 2020 to 1st August 2021 using the databases PubMed, Embase and Web of Science. Grey Literature was searched through Google Scholar. A manual search was conducted across the reference lists of the included articles.

Broad search terms were used to capture all articles relevant to the evaluation of smartphone apps for teledentistry. The search terms used were as follows: teledentistry and smartphone dentistry, smartphone applications and dental consultation. All articles published till date have been included.

Study selection

The abstracts of the resultant de-duplicated search were screened and categorized into (1) obtain full article for review or (2) exclude. The full articles were reviewed. During the screening of abstracts and full articles, studies about dental consultations were included.

Excluded articles were categorized into the following exclusion categories: not dentistry related, or if they were e-posters or conference proceedings.

The remaining articles were included for qualitative review. Empirical articles and systematic reviews about mobile app interventions for online dental consultations were included for phase 2 app review.

The findings were compared to achieve consensus and the discrepancies were resolved until a final list of studies pertaining to the evaluation of teledentistry apps was compiled.

Risk of bias and quality assessment

Risk of bias assessment was done by two independent reviewers. Case reports were assessed against the against the Joanna Briggs Institute Critical Appraisal Checklist for case reports, observational and nonrandomised studies were assessed against the ROBINS-I assessment tool, and RCTs were assessed against the Cochrane Risk of Bias 2 tool.[8-10]

Each study was assessed by one researcher, with another researcher checking the first assessment. We rated each selected article on the Methodological quality (MQ) of the study based on ratings of study-bias assessment.[11] The studies were assigned a grade of evidence based on the GRADE approach.[12]

Phase 2

Identified which apps from the literature review were available in the app stores

Each app identified in the scientific literature during phase 1 was searched for in each of the following online app stores: app store for iPhone and Google Play for android. Apps with the same name and developer of those listed in the literature were considered a match. A list was created to identify which apps having any scientific grounding were available and which stores offered them.

Phase 3

Identified the top teledentistry apps available in the app stores

An online search was conducted from 1st August, 2020 to 30th April 2021 via Google search engine using keywords, 'teledentistry apps on App store.' A second search was made on Google Play store using keywords, 'dental consultation' and 'teledentistry.' Only those apps were included which are available on either Google Play store or on App store and aim to provide online dental consultation. Those excluded were non- dental apps, apps based on knowledge for dental students, dental clinic management and booking appointments, dentistry-based games for children.

RESULTS

Phase 1

Identified all teledentistry apps reported in the scientific literature total of 305 records were identified, and following de-duplication 258 records were identified for screening. A summary of the number of records at each stage of the review can be found in Figure 1 (Figure 1). 11 studies were considered eligible.[11-21] A summary of study characteristics is provided in the Table 1. The earliest study was published in 2013. The quality assessments of case reports have been charted. Out of the 8 observational studies, 7 (87.5%) showed moderate risk of bias and 1(12.5%) was at low risk. The single randomized control trial included in the review was at serious risk of bias (Table 1).

Phase 2

Identified which apps from the literature review were available in the app stores.

The results are described in Table 2.

Phase 3

Identified the teledentistry apps available in the app stores

The results are described in Table 3.

Table 1: Articles supporting teledentistry apps (PubMed, Embase, Web of Science).

Study	Smart-phone app name	Aims and objective	Condition	Sample	Study design	Intervention and comparison
Heather et al.[13]	Dental monitoring	Comparing the app against a clinical procedure Participant: patients	Calculating the intercanine and intermolar widths in orthodontic patients undergoing Rapid maxillary expander (RME) treatment.	N=12 Age: 10-17 years Mean age N/A Sex ratio= 1:2	Pilot study	Intervention: the reliability and the accuracy of an orthodontic monitoring software application. to calculate the intercanine and intermolar widths in orthodontic patients undergoing rapid maxillary expander (RME) treatment Comparisons: Measurements made on plaster models produced during in-office visits.
Estai et al.[14]	Teledental	Aimed to evaluate users' acceptance of a teledentistry model utilizing a smartphone camera Participant: five independent dental practitioners and 17 trained teledental assistants (dental students, dental assistants, dental practitioners)	dental caries screening and to identify a number of areas for improvement of the system	N=20 Mean age: 34 yrs Sex ratio 1:4	Proof of concept trial	Interventions: dental caries screening using smartphones app Comparisons: N/A
Haron et al.[15]	MeMoSA	To evaluate the feasibility of using Mobile Mouth Screening Anywhere (MeMoSA®) to facilitate early detection of oral cancer.	Early detection of oral cncer			Interventions: early detection of oral cancer using MeMoSA Comparisons: N/A
Hansa et al.[16]	Dental monitoring (DM)	To compare the effects of Invisalign® with and without DM and to further evaluate patient	treatment duration, number of appointments, number of refinements, total	Group DM- N= 88 Mean age: 25.1 Sex ratio: 63:25	RCT	Interventions: N/A Comparisons: DM with Invisalign® on grounds of treatment duration, number of appointments, number of refinements, total number

Continued.

Study	Smart-phone app name	Aims and objective	Condition	Sample	Study design	Intervention and comparison
		perspectives of DM.	number of refinement aligners, and time to initial refinement	Group control- N= 67 Mean age: 25.4 Sex ratio: 50:17		of refinement aligners, and time to initial refinement
Mladanovic et al.[17]	XPA3 online	The aim of this paper was to present telemedicine consulting in the patient preparation and planning of prosthetic tooth replacement.	prosthetic tooth replacement.	Case 1: 67-year-old male patient Case 2: A 52-year-old, male patient Case 3: A female patient, aged 48 years	Case report	Intervention: present telemedicine consulting in the patient preparation and planning of prosthetic tooth replacement. Comparisons: N/A
Stein et al[18]	DentaCom	To explore the feasibility of prospective patients using a smartphone to capture clinical information that help dentists make fundamental clinical decisions when they cannot examine them directly.	Triage of dental emergencies	N=20 Age: 18-61 Mean Age: 32.4 Sex Ratio 9:11	Proof of concept trial	I: triage of dental emergencies C: N/A
Caruso et al.[19]	Dental monitoring (DM)	To describe two cases in which DM system was essential to achieve the control of certain movements: it was possible to follow the movement, even if complex, such as the anterior cross of an adult patient and a lack of space in the canine of the	Correcting biomechanics by analysing fit and retention of aligners	Case 1: 11 years old female patient Case 2: 57 years old male	Case Report	Intervention: Case 1: Remote monitoring of the case through DM app. Case 2: DM system allowed to strictly follow patient compliance and monitor the resolution of the anterior cross

Continued.

Study	Smart-phone app name	Aims and objective	Condition	Sample	Study design	Intervention and comparison
		growing patient				
Kuriakose et al[20]	Dental monitoring (DM)	To assess the accuracy of DM software in assessing the achievement of treatment goals in patients undergoing rapid palatal expansion treatment and patient acceptance of DM.	Assessment of rapid maxillary expansion	N=20 Median age: 11 years	Original Research	Intervention: The accuracy of DM software in assessing the Maxillary intermolar width (mm) and posterior crossbite correction. Comparison: with digital models and intraoral measurements.
Morris et al[21]	Dental Monitoring (DM)	To test the accuracy of the 3-dimensional (3D) digital dental models generated by the Dental monitoring (DM) smartphone application in both photograph and video modes	3D digital dental models generated by the smartphone app	Ten typodonts were set up in class I anterior crowding wax forms	Original research	Comparison: 3D digital dental models generated from the iTero Element intraoral scanner
Perdoncini et al.[22]		To assess the feasibility and accuracy of synchronous teleconsultation in oral medicine.	Remote assessment of oral lesions using a smartphone app	N= 33 Age: 25-33 years	Original research	Intervention: Video call assisted consultation and diagnosis of oral lesions using their images taken through a smartphone app. Comparison: assessment of the oral lesion in person
Estai et al[23]	Teledental	to evaluate the efficacy of a mobile teledentistry approach using a smartphone camera for remote screening of dental caries	Caries assessment	N=100 Male;Female =16:9	Original research	Intervention: Caries assessment using smartphone app Comparison: Face to face caries assessment

Table 2: Apps available from literature search available on app stores.

App name	Google play store	Apple app store
Dental monitoring	Present	Present

Continued.

App name	Google play store	Apple app store
Teledental	-	-
MeMoSa	-	-
XPA3 online	-	-
DentaCom	-	-

Table 3: Smartphone teledentistry apps available on Google play store and Apple app store.

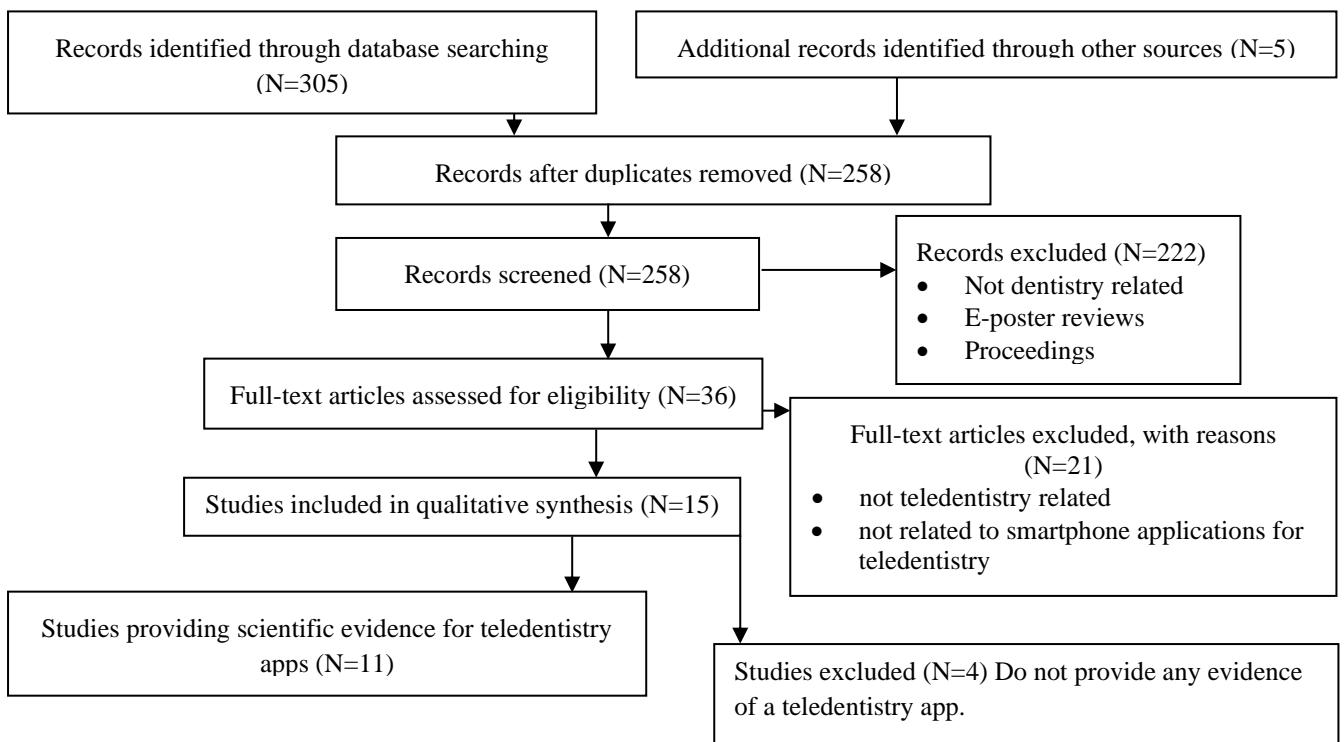| Teledentistry apps available both on Google play store and Apple app store	Teledentistry apps available on Google play store	Teledentistry apps available on Apple app store
Dentulu patients- virtual dental consultations Dentists for me Dentalchat Dental monitoring Teledentistry Smilemate Teledentix Dentocontrol Couch dentist Straight teeth direct DDS anywhere Dentoxpert Toothpic	Dguard - dentist, book appointment, consult online Dentist Teledent DenToGo monitoring	Denteractive Smiles to go dentistry Dentist on demand Dentalstat

Figure 1: The PRISMA model for literature review of teledentistry apps.

DISCUSSION

Smartphone apps have been found to be useful in medical practice, as they assist in monitoring patient health, rehabilitation and can be used to collect clinical data.[24] Teledentistry based smartphone apps are equally important in dental practice.

Treatment planning and expanding the options of treatment phasing in complex cases by coordination, as provided by these apps, in patients, providers, and specialists, providing immediate emergency and remote contact with a dentist, monitoring teeth movement remotely thereby reducing frequent trips to a hospital or dental clinic and waiting in dental

practices, are some of the many advantages of teledentistry.

Moreover, teledentistry based consultations reduce overhead costs, maximize time for both providers and patients, and allow a streamlined workflow. However, a search of the popular app stores showed that only one app out of the 5 apps identified through literature review in this study remained available for consumers for teledentistry retrieved via keyword search. This suggests that most of the teledentistry apps that are scientifically supported remain unavailable to the consumers and are unlikely to be found by them. The earliest study on teledentistry was done in 1994 as a military project of the United States Army (U.S. Army's Total Dental Access Project), aiming to improve patient care, dental education, and effectuation of the communication between dentists and dental laboratories.[25] It is inevitable for such technological interventions in clinical dentistry to be flawless.

Teledentistry requires proper internet connections, a backup communication system and technical support group and accurate transmission of data, which might not be always available. This also effects the clinical diagnosis and final outcomes.[26] All the studies were designed with different aims. Study by Hansa et al aimed to compare teledentistry systems with normal routine clinical procedures. Study by Stein et al assesses patient response to teledentistry; Nabihah Haron et al tested the feasibility of the apps in diagnosing clinical conditions such as oral cancer.[15,16,18] The study by Kuriakose et al examined rapid palatal expansions in patients remotely.[19] However, no study was conducted in the geriatric age group to assess the acceptance of teledentistry by the geriatric population where such technological interventions are highly recommended. The above studies examined the effectiveness of the apps to achieve the objectives of the studies. However, the studies should also include the details of the app stores which offer their apps to the customers.

Along with it, literature-based studies for apps should also include user ratings and reviews, performance, evaluation, and user analytics for the apps, which are generally provided in the app stores, and an analysis of the same. Although other systematic reviews of mHealth tools (apps in general) opine that literature-based approach may not be the best fit for app review, the PRISMA method of systematic review, served as an effective methodology for this review and is a recommended method for future systematic reviews on teledentistry apps.[27]

The app searching process was tedious as the app stores yielded a number of other apps along with teledentistry apps. The search keywords- 'teledentistry apps on app store', 'dental consultation' and 'teledentistry.' yielded 499 apps including dental gaming apps intended for children; educational apps for dental students; online dental stores; apps that are an online platform for the

dentists to connect with other fellow dentists and patient education-based apps, and only 21 teledentistry apps. Thus only 4.2% of the search results were related to teledentistry. This indicates the hassle in searching for teledentistry apps. Therefore, mHealth apps should be more clearly categorized before being made open for the general public to search them on the app stores.

Some search results were irrelevant to teledentistry based apps in both the app stores. Similarly, no correlation was found between the amount of options offered and the amount of scientifically supported apps among the selections. This highlights a disconnect between the terminology consumers use to search for health apps and the terminology app developers and app stores use to index apps, thus making the process of app searching difficult. It is very evident that very few apps qualified our scientific review process whereas the number of apps available on the app stores for teledentistry are greater. This may be due to the fact that app developing and making them available on the app stores has become a faster process due to the rapidly advancing technologies and with the presence of skilled app developers.

Compared to it study designing, executing followed by publishing results, is a much slower process than the fast-paced timeline for app development. Dental monitoring (DM) is the only app that is readily available in both app stores and is backed with literature evidence. 5 out of 11 studies (45.5%) included in the review provide valuable evidence for the app. Heather Moylan et al and Kuriakose et al calculated the inter-canine and intermolar widths in orthodontic patients undergoing Rapid maxillary expander (RME) treatment using the Dental monitoring app and compared it with measurements made using plaster models and digital models, concluding that both the measurements are comparable.[13,20] Hansa et al conducted an RCT to compare the effects of Invisalign® with and without DM and to further evaluate patient perspectives of DM and found that DM appears to be generally well received by patients.[16]

Teledentistry mediated through smartphone apps can be useful in various aspects of dentistry. General dental consultations, monitoring tooth movement for orthodontic treatments, caries assessment, oral hygiene assessment, smile analysis and follow-up consultations (by keeping a record of pre-treatment and post-treatment conditions), emergency consultations and dental triaging can be facilitated by mobile dental apps in times of restricted dental services during a lockdown situation.[28]

Limitations

It could not be determined whether an app was previously available to the customers either in the form of studied or earlier version with a different app name. The methods used determine only if an app is available at the time of search. Search functions of each app store are different. Each store uses unique proprietary criteria for obtaining

the results. Thus, it is problematic to compare results over different app store platforms. The article reviews apps only in PubMed database. Most of the journals in PubMed are peer reviewed. Hence, there may be publication bias towards studies that have positive results.[29] Therefore studies demonstrating negative effects of teledentistry apps might not show up in the results, thus contributing less to the review.

CONCLUSION

The small number of articles related to teledentistry apps, are suggestive of the fact that there is not much evidence-based literature on the topic. However, it is the need of the hour that various teledentistry apps present in the apps stores are reviewed and the patient attitude towards them be studied. More importantly literature publishing process should match the timeframe required for developing an app and publishing it on the apps stores. This would enable app developers to present their apps with a literature backup, thus making it easier for reviewers to study them comprehensively. Also, an important factor for success of teledentistry is willingness of the dentist to adapt to changing circumstances and modify existing dental practice systems. It is advisable to introduce the tools of teledentistry as part of curriculum for dental undergraduates to prepare them for effective and efficient services even during difficult times. This would further open research options in teledentistry, and much more scientific backup for teledentistry apps.

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