EVIDENCE-BASED APPLICATION OF TELEDENTISTRY: A SYSTEMATIC REVIEW

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ABSTRACT

Background Teledentistry has emerged as a potential alternative to in-person dentistry, offering new possibilities for oral healthcare delivery and prompting need for a comprehensive evaluation of its efficacy and global applicability.
Objective To determine most common fields of teledentistry application, evaluate its effectiveness compared to in-person dentistry, and analyze its utilization in various countries based on the economic context.
Data source This systematic review conducted a literature search from five electronic databases: PubMed, Embase, Web of Science, Clinical Trials.gov, and the International Clinical Trials Registry Platform.
Study selection Evidence-based studies published in English (2011-2021), using teledentistry.
Data extraction Primary outcome: teledentistry usability. Secondary focus: utilization across economic strata. Methodological quality was assessed using the Down and Black checklist.
Data synthesis Of 34 reviewed studies, 18 favored a combined approach, 6 found comparable efficacies, 9 favored teledentistry, and 1 preferred in-person dentistry for anxiety management. Effectiveness was evident across economic settings (22 high-income, 6 upper-middle-income, 6 lower-middle-income nations). Teledentistry showed efficacy in oral health promotion and interprofessional consultation. We found that orthodontics is the most common specialty in teledentistry. Generally, teledentistry showed positive outcomes in patient education and behavior modification across various dental specialties. The adoption of teledentistry adoption might depend on economic status, highlighting the need for further research and implementation strategies in low-income countries to address global oral health disparities. This review demonstrates teledentistry's effectiveness as a versatile tool across diverse economic settings, emphasizing the need for focused research in low-income regions to bridge the global oral healthcare divide.

KEYWORDS

Dentistry; Teledentistry; Oral Health; Mobile Applications; Evidence-Based.

1. Introduction

The advent of teledentistry as a promising tool for enhancing dental care accessibility, particularly in underserved and remote areas. Teledentistry has significant potential to improve access to dental services, deliver preventive care, and facilitate remote specialist consultations [1]. The integration of teledentistry into oral healthcare delivery was established through advancements in telecommunication technologies, including high-resolution imaging and secure communication platforms. This early adoption was primarily motivated by the necessity to address disparities in dental care access and enhance efficiency in patient management [2].

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The COVID-19 pandemic precipitated a substantial acceleration in teledentistry adoption. The widespread implementation of social distancing protocols and the transient suspension of dental practices emphasized the imperative for alternative care delivery modalities. A previous study reported that teledentistry emerged as an indispensable instrument in ensuring the continuation of care delivery amidst the pandemic, facilitating remote consultations, prioritizing emergent cases, and disseminating oral health education while reducing the risk of transmission [3]. The adoption of teledentistry during the pandemic underscores its transformative potential in oral healthcare delivery. One is Mobile Oral Health (mOralHealth), which primarily focuses on enhancing oral health through knowledge dissemination, skill development, and community-based healthcare access [4]. These interventions helped sustain oral health services during the pandemic by providing alternative care delivery, thus reducing the risk of virus transmission. At the same time, ensuring patients continued to receive necessary dental support. One oral health intervention is teledentistry, which addresses remote diagnosis and treatment planning via communication technologies [5]. The World Health Organization (WHO) and the American Dental Association (ADA) define teledentistry as providing health services using electronic information, imaging, and communication technologies to deliver and support oral healthcare services such as dentist-patient communication, and inter-professional communication among general dental practitioners, dental specialists, and medical professionals from other disciplines [6], particularly in situations where geographical proximity is a critical factor [7]. ADA further delineates teledentistry into four primary modalities: synchronous (live video), asynchronous (store and forward), remote patient monitoring (RPM), and health education (mHealth) [8]. The wide array of teledentistry interventions includes diagnosis (tele-diagnosis), consultation (tele-consultation), treatment (tele-treatment), and dental information dissemination and education (tele-education) through interactive audiovisual aids and data communication systems [9]. Although there is empirical evidence suggesting that teledentistry can effectively complement in-person management [1], with diverse applications ranging from patient education on oral health and hygiene improvement, particularly in orthodontic patients [10-12], to enhancing specific dental hygiene practices through various digital platforms [13-17], there is a significant gap in the literature regarding the applicability of teledentistry concerning countries' economic status. Low-income countries may find it challenging to implement such teledentistry interventions, considering factors such as dental clinic availability and geographical accessibility.

The sustained integration of teledentistry into routine dental care depends upon overcoming technological obstacles, ensuring equitable reimbursement policies, and maintaining the inviolability of patient privacy and data security. Evidence suggests that conventional dental treatment integrated with digital support has demonstrated the potential for improving diagnostic accuracy, treatment efficacy, and prognostic outcomes [18-21]. The affirmative experiences reported by both patients and healthcare providers have established a robust foundation for the continued utilization and expansion of teledentistry in the post-pandemic landscape. Notwithstanding these advancements, there remains a gap in comprehensive research evaluating the comparative effectiveness of teledentistry encompassing diagnosis, consultation, and treatment compared to in-person dentistry across various dental specialties. Therefore, the effectiveness of teledentistry compared to in-person dentistry in fields of dentistry was evaluated in this systematic review.

2. Methods

This study employs a systematic review methodology to determine the most common fields of teledentistry application, evaluate its effectiveness compared to in-person dentistry, and analyze its utilization in various countries across diverse economic contexts. The research protocol adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and is registered with the International Prospective Register of Systematic Reviews (Registration Number CRD 42022259600) [22].

2.1. Search strategy and focused questions

A comprehensive literature search was conducted across five electronic databases: PubMed, Embase, Web of Science, ClinicalTrials.gov, and the International Clinical Trials Registry Platform. Supplementary hand searches were performed to ensure comprehensive coverage. Detailed information is provided in supplementary Table 1 (Table 1).

The following three questions were formulated using the PICO approach to assess whether teledentistry is more effective than in-person dentistry in contemporary dental fields:

1. In which of dentistry fields is teledentistry most utilized?

2. How does the effectiveness of teledentistry compare to in-person dentistry in terms of patient education, behavior modification, professional communication, and cost-effectiveness?

3. In which countries is teledentistry more frequently utilized based on economic context?

Table 1. Characteristics of the Included Studies

No.	Authors/ Year of Publication (Country)	Study Population	Target age groups (Number of Subjects)	Tele-dentistry Intervention(s)	Form of Tele-communication/ Devices	Comparison Group	Main Outcomes	Summary of results (∂, ∇, ♭, ∉, √)
Orthodontic Dentistry								
1	Jejurikar et al., 2014 (India)	patients (full fixed appliances in both arches)	Young adults: 13-19 years (n=50)	Weekly text message reminders after OHI, once a week for 4 months	Remote patient monitoring (RPM)	Only OHI	Plaque index (PI), white spot lesions (WSL)	♭
2	Eppright et al., 2014 (USA)	patients (active treatment with full fixed appliances in both arches)	Young adults: 11-19 years (n=42)	One parent or guardian of each patient received a text message and the patient received oral hygiene instruction.	Mobile health (mHealth)	Only Oral hygiene instruction	Bleeding index (BI), Modified Gingival Index (MGI), and Plaque Index (PI)	∂
3	Bowen et al., 2015 (USA)	patients (fixed maxillary edgewise appliances)	Young adults: 10-18 years (n=50)	Audiovisual presentation on oral hygiene care followed by 2-3 text messages per week for 4 weeks, then 1 text message per week for 8 weeks.	Asynchronous (store and forward)	Only audiovisual presentation about oral hygiene care	Planimetry-based evaluation of plaque values evaluation (Digimizer software)	♭
4	Al-Silwadi et al. 2015 (United Kingdom)	patients (scheduled to receive fixed orthodontic appliance)	Others: ≥13 years (n=60)	Following the distribution of oral health education and leaflets on oral health and fixed appliance care, an email was sent inviting participants to view a video providing the same information.	Other	Only oral health education, leaflets on oral health and care of fixed appliances	Knowledge of dental and appliance care	♭
5	Abdaljawwad, 2016 (Iraq)	patients (fixed orthodontic appliances)	Young adults: 17-23 years (n=34)	After OHI, text messages twice a week for 4 weeks and once a week for 8 weeks.	Asynchronous (store and forward)	Only OHI	Bleeding Index (BI), Modified Gingival Index (MGI), Plaque Index (PI)	♭
6	Cozzani et al., 2016 (Italy)	patients (begin fixed orthodontic treatment)	Others: mean age: 13.5 ± 1.7 years (n=84)	1. after the OHI, a reinforced text message 2. phone call 5-7 hours after initial bonding	Mobile health (mHealth)	Only OHI	Oral Hygiene Index, by Silness and Loe's Modified Index, Plaque Index (PI)	♭

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7	Zotti et al., 2016 (Italy)	patients (full fixed appliances in both arches)	Others: mean age: control group 13.6 years, study group 14.1 years (n=80)	OHI by taking video tutorials in WhatsApp chat rooms and sharing selfies as part of the "Brush Game.	Asynchronous (store and forward)	Only OHI	Plaque index (PI), gingival index (GI), white spot (WS), caries presence	♭
8	Li et al., 2016 (China)	patients (begin fixed appliance and single-phase orthodontic treatment)	Young adults: 12-21 years (n=244)	Signed up for a WeChat account and received twice-weekly behavioral reminders and 2-3 educational messages per week throughout the treatment period.	Mobile health (mHealth)	Only orthodontic strategy and pretreatment education as in the WeChat group	Length of treatment Failure to keep appointments, tardiness Bracket bond failure Orthodontic PI, modified gingivitis index	∂
9	Iqbal et al., 2017 (Pakistan)	patients (full-fixed orthodontic appliances)	Young adults: 15-25 years (n=100)	Weekly text message reminders after OHI for 60 days	Asynchronous (store and forward)	Only OHI	Bleeding Index (BI), Modified Gingival Index (MGI), Plaque Index (PI)	♭
10	Alkadhi et al., 2017 (Saudi Arabia)	patients (fixed orthodontic appliances)	Others: ≥12 years (n=44)	Mobile application for video oral hygiene instruction and proactive reminders three times a day for one month.	Mobile health (mHealth)	Only OHI during visits	Plaque and Gingival indices (PI and GI)	∂
11	Kumar et al., 2018 (India)	patients (fixed orthodontic appliances)	Young adults: 13-19 years (n=60)	Weekly text message reminders after OHI for 3 months	Asynchronous (store and forward)	Only OHI	Plaque index (PI) and WSL status	♭
12	Deleuse et al., 2020 (Belgium)	patients (full-fixed orthodontic appliances)	Young Adults: 12-18 years (n=38)	Interactive oscillating/rotating electric toothbrush connected to a brushing assistance app	Mobile health (mHealth)	Only oscillating/ rotating electric toothbrush	Plaque index (PI), gingival index (GI), white spot lesion (WSL)	∇
13	Scheerman et al., 2020 (Netherlands)	patients (fixed orthodontic appliances)	Others: mean age: study group 13.2±1.01 years, control group13.5±0.97 years (n=121)	Use the "White Teeth" mobile application to reinforce plaque control daily for 12 weeks.	Mobile health (mHealth)	OHI and oral health education when dental visits	Plaque index (PI) and Bleeding on marginal probing index (BOMP)	♭

14	Al-Moghrabi et al., 2020 (UK)	participants (scheduled for removable retention with thermoplastic retainer (TPR))	Young adults: 12–21 years (n=84)	Use “My Retainers”, a mobile application that reminds users to wear orthodontic retainers	Mobile health (mHealth)	Reminder of retainer wear chart	Stability, plaque level, bleeding during probing and depth of probing, level of patient experience and knowledge regarding retainers	∇
15	Farhadifard et al., 2020 (Iran)	patients (started their fixed orthodontic treatment)	Others: mean age: study group 18.7 ± 3.87 years, control group: 19.27 ± 3.65 years (n=120)	In addition to conventional oral hygiene instruction, the team educated the patients to use a smartphone app (Brush DJ) that includes timers and daily reminders to assist in improving oral hygiene.	Mobile health (mHealth)	Conventional oral hygiene instruction	Plaque Index (PI) and Gingival Index (GI)	∂
16	Sangalli et al., 2021 (Hong Kong)	patients (scheduled to start an orthodontic treatment)	Others: mean age: study group 24.9±10.9 years, control group: 6.3±3.2 years (n=30)	A scan box and cheek retractor (Dental Monitoring@) were provided and the patient was instructed to perform a monthly intraoral scan.	Remote patient monitoring (RPM)	Only in-person toothbrushing instruction	Plaque Index (PI), Gingival Index (GI), and White Spot Lesions (WSL)	♭
Preventive Dentistry								
17	Jadhav et al., 2016 (India)	social work colleges (two different)	Young adults: 18-20 years (n=400)	OHI and oral health education followed by oral health education text messages sent twice a week for 3 months	Mobile health (mHealth)	Only OHI and oral health education	Oral Hygiene Index and Gingival Index (GI)	♭
18	Williams et al.,2018 (USA)	participants (mild to moderate periodontitis)	Adults: 21-80 years (n=60)	View oral hygiene instruction, brushing and flossing presentations on computer	Asynchronous (store and forward)	Only OHI with visual aids	Plaque score (PS) and bleeding index (BL)	∇
19	Marchetti et al., 2018 (Brazil)	students (technical high school)	Young adults: 14-19 years (n=263)	1. Verbal oral health education and reinforced messages via mobile app for 30 days. 2. oral health education video and reinforced messages via mobile app for 30 days. 3. oral health education video only	Mobile health (mHealth)	Only verbal oral health education	Knowledge Score (KS), simplified oral hygiene index (OHI-S), Gingival Bleeding Index (GBI)	♭

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Pediatric Dentistry								
26	Plonka et al., 2013 (Australia)	children (areas of low socioeconomic status)	Others: Infants within two months of birth and caregivers (n=246)	Home visits and phone calls	Other	Without intervention	Prevalence of Early Childhood Caries (ECC)	∂
27	Hashemian et al., 2015 (USA)	Mothers (bringing a child aged 5 years or younger for dental care)	Others: 18-56 years	Along with the usual care printed materials, they received text messages regarding oral health information.	Mobile health (mHealth)	Only the usual print materials	Oral health knowledge and oral health behaviors (including improving oral health behaviors for their children)	♭
28	Iskander, M., et al., 2016 (USA)	adult (accompanied a child to the dental appointment)	Adults 36-45 years (n=89)	Oral health education with "Dental Trauma mobile healthcare" application (permanent tooth avulsion scenario)	Mobile health (mHealth)	Oral health education with "Save Your Tooth" poster (assuming primary tooth injury)	Knowledge of permanent tooth avulsion	∂
29	Zotti et al., 2019 (Italy)	patients (3 private dental practices)	Others: 4-7 years with one of their parents (n=100)	Use the OHI motivational mobile apps "Time2Brush" and "Brusheez-The Little Monsters Toothbrush Timer" for children over and under five, respectively.	Mobile health (mHealth)	Only OHI	Plaque Index (PI), presence of caries, localization of carious lesions	♭
30	Alkilzy et al., 2019 (Germany)	children (an almost complete deciduous dentition)	Children: mean age: 5.1 ± 0.6 years (n=49)	OHI adds toothbrush mobile application	Mobile health (mHealth)	Only OHI	Plaque and papillary bleeding indices (QHI, PBI)	♭
Oral and Maxillofacial Surgery								
31	Salazar-Fernandez et al., 2012 (Spain)	patients (TMDs)	Children: 1-5 years (n=1052)	Digital TMJ and panoramic radiographic consultation via intranet e-mail	Asynchronous (store and forward)	Conventional consultation system at the hospitals	Clinical effectiveness, consultation costs, and patient satisfaction	∇

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20	Araújo et al., 2019 (Portugal)	patients (> 20 teeth, and bleeding on marginal probing index over 0.5)	Others: mean age: control group 13.6 years, study group 14.1 years	OHI using intraoral camera during the visit and/or text messages between visits	Asynchronous (store and forward)	Only OHI	Bleeding on marginal probing (BOPM), dental hygiene, behavior change	♭
21	Scheerman et al., 2020 (Iran)	students (public high school)	Others: high school students, 12–17 years, with and without their mothers (n=791)	1. use of the Dental Health telegram channel for patients to receive oral hygiene education via text message or video 2. use of the Telegram channel for mothers to receive oral health education and instructions for teaching and monitoring their children's oral health.	Combination	Without intervention	Psychosocial variables, toothbrushing behavior, Visual Plaque Index (VPI), Community Periodontal Index (CPI)	√
22	Vpk et al., 2020 (India)	patients (cerebral palsy)	Children: 4-12 years (n=53)	Video based oral health education following OHI	Mobile health (mHealth)	Only OHI	Oral hygiene status, including the simplified oral hygiene index (OHI-S), plaque index (PI), and gingival index (GI)	♭
23	Shida et al., 2020 (Japan)	participants (Kyoto University)	Others: ≥18 years, mean age: control group 25.0 years, study group 26.0 years (n=112)	After the video based OHI, a real-time visualization brushing instruction device (GUMPLAY) linked to a mobile application was used for 4 weeks.	Mobile health (mHealth)	After the OHI by video, brush with the same device without connecting it to the application.	Plaque control record (PCR) score	∇
24	Marchetti et al., 2020 (Brazil)	students (high school)	Young adults: 14-19 years (n=291)	Video-based dental flossing and counseling to communicate oral hygiene knowledge twice a day for 30 days (VD + smartphone app, VD without app)	Mobile health (mHealth)	Dental floss and oral counseling (OR+ app, OR without app)	Simplified oral hygiene index (OHI-S) and gingival bleeding index (GBI)	∂
25	Lee et al., 2021 (Korea)	adults (enrolled at a senior college and senior welfare center)	Others: ≧65 years (n=73)	1. Receive lecture-type oral health education using PowerPoint slides (non-app use group) 2. Receive oral health education using a smartphone application developed in this study.	Mobile health (mHealth)	Without intervention	Oral health knowledge score, O'Leary index, and tongue coating	∇

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32	Wang et al., 2019 (Taiwan)	patients (admitted at a general hospital for curative oral cancer surgery)	Adults: 30–82 years (n=60)	A 12-week intervention program (warm compresses, masticatory muscle massage, and jaw exercises) three times a day, with additional telephone support after discharge.	Other	Only 12-week intervention program	Maximum Interincisal Opening (MIO)	b
33	Takeuchi-Sato et al., 2019 (Japan)	patients (TMDs)	Others: mean age: 30.7 ± 8.7 years, (n=30)	Cognitive Behavioral Therapy (CBT), email recording and reminder system, sticky note reminders	Mobile health (mHealth)	Brief oral instructions to avoid non-functional tooth contact (n-FTC) during the day	Pain-free opening aid	∂
34	Omezli et al., 2020 (Turkey)	patients (scheduled to undergo impacted lower third molar removal)	Others: mean age: study group 22.93 ± 5.83 years, control group 23.12 ± 4.99 years (n=113)	Third molar surgery video	Other	Third molar surgery verbal information	Anxiety and pain scale	¢

- Teledentistry is more favorable than the conventional method, - Teledentistry is not different from the conventional method, - Teledentistry along with conventional methods is more effective than conventional ones alone, - Teledentistry is less favorable than the conventional method, - others (Teledentistry was effective to deliver oral health education among high-school students, especially with the involvement of their mothers), OHI – Oral Health Instruction

2.2. Eligibility criteria

The study included evidence-based research published in English between January 2011 and December 2021, focusing on teledentistry interventions. Eligible studies involved participants of all ages and sexes who received teledentistry services, with conventional dental treatment or oral health instruction as the control or comparison group. Primary outcomes assessed teledentistry's usability through clinical indices, behavioral modifications, Knowledge_Attitude_Practice (KAP) metrics, or cost-effectiveness analyses, while a secondary outcome explored teledentistry utilization concerning countries' economic status. Studies were excluded if they lacked comparison with conventional methods, were not original research, or were not written in English.

2.3. Study selection, and data extraction

Two independent reviewers (TH and BP) conducted the literature review and screened titles and abstracts to identify studies that met the inclusion and exclusion criteria. They compiled lists of selected studies for each research question, which were then compared. By discussing each source, they reached a definitive consensus on which studies to include for each question. Any discrepancies during the screening and selection processes were resolved through discussions between the two reviewers. If disagreements persisted, additional reviewers (RK and TZ) were consulted to reach a consensus. Once consensus was reached, the full texts of the selected literature were collected and independently assessed by the same reviewers. Only studies with sufficient data were included in the analysis, with discrepancies resolved through discussion. The reviewers extracted data using a standardized form, collecting general information such as authors, title, year of publication, journal name, study aims, design, level of evidence, relation to COVID-19, number of participants, countries of research, study setting, dental specialty, type, and mode of teledentistry intervention, comparison with in-person dentistry, and outcomes. Outcome information was extracted from the included studies.

2.4. Quality assessment

Two reviewers independently assessed the quality and risk of bias in the data extraction process, following the guidelines from a modified version of the Downs and Black checklist [23]. The quality of each including randomized controlled trials (RCTs), and non-randomized controlled trials (NRCTs) was evaluated. This instrument evaluates the risk of bias across 27 items in five sub-scales (Table 3). This instrument is based on the following components that define study quality and evaluate the risk of bias: reporting, external validity, internal validity (bias and confounding (selection bias)), and power. The bias was rated on a 4-point scale (No risk 0, partial risk 1, clear risk 2, UTD unable to determine) for each domain, depending on the reviewers. Studies were categorized into four quality levels based on their scores [24] (Table 4). The risk of bias was summarized by considering the assessments for each domain and synthesizing them into an overall judgment of the study: (excellent 26-28; Good 20-25; Fair 15 -19 or poor less than or equal to 14). Further disagreements were resolved through discussion with input from other reviewers (RK and TZ).

2.5. Data synthesis and management

Data synthesis and management were facilitated through Microsoft Excel. The citation management tool Endnote X9 (Clarivate Analytics, New York, United States) was used for reference management.

2.6. Reporting

The PRISMA flowchart and checklist were utilized to ensure transparent and comprehensive reporting of the literature search and review process.

3. Results

3.1. Characteristics of the included articles

This systematic review analyzed 34 studies, comprising 31 randomized controlled trials and three nonrandomized controlled trials [6,15,25]. The literature search across multiple databases yielded 1,689 initial results, with 34 articles meeting the inclusion criteria after rigorous screening (Figure 1). The excluded studies are detailed in the supplementary materials (Table 2). Detailed characteristics of the included articles are shown in Table 1. The included studies demonstrated the significant utility of teledentistry at the individual level, primarily in oral health education, behavioral modification, and reinforcement. Most studies were conducted in educational settings (high schools and dental colleges) and healthcare facilities. One study specifically examined professional communication [6] while several incorporated follow-up reminder systems. Notably, no studies provided evidence of tele-treatment implementation. The primary outcome measures utilized were clinical indices, often in combination with knowledge assessments, behavioral modifications, Knowledge-Attitude-Practice (KAP) evaluations, and cost-effectiveness analyses.

Table 3. Distribution of the Number of studies based on the Countries' economic status

No.	Country	Income Economy*	Number of Studies
1	Belgium	High	1
2	Germany	High	1
3	Italy	High	3
4	Japan	High	2
5	Netherlands	High	1
6	Portugal	High	1
7	Saudi Arabia	High	1
8	Spain	High	1
9	Taiwan	High	1
10	UK	High	2
11	USA	High	3
12	Australia	High	1
13	Korea	High	1
14	Hong Kong	High	1
15	Brazil	Upper-middle	2
16	China	Upper-middle	1
17	Iraq	Upper-middle	1
18	Turkey	Upper-middle	1
19	India	Lower-middle	5
20	Iran	Lower-middle	1
21	Parkistan	Lower-middle	1

*Countries' income economy according to the World Bank is described in Supplementary file (Table 4)

3.2. Teledentistry usage according to fields of dentistry

According to the current review, teledentistry interventions can be broadly categorized into three groups: customized applications for oral health education, in-office education with remote reinforcement measures, and supervision tools connecting specialists with general dentists to minimize referrals. Table 2 provides a comprehensive distribution of study outcomes across various dental specialties. The included studies covered various dental specialties, with orthodontics (15 studies) being the most represented [10-14,17,20,25-33], followed by preventive dentistry (8 studies) [15, 18, 21,34-39], pediatric dentistry (5 studies) [40-44], and oral and maxillofacial surgery (5 studies) [6,19, 45,46]. Each specialty employed diverse objectives, methodologies, and outcome measures to assess teledentistry's efficacy compared to in-person

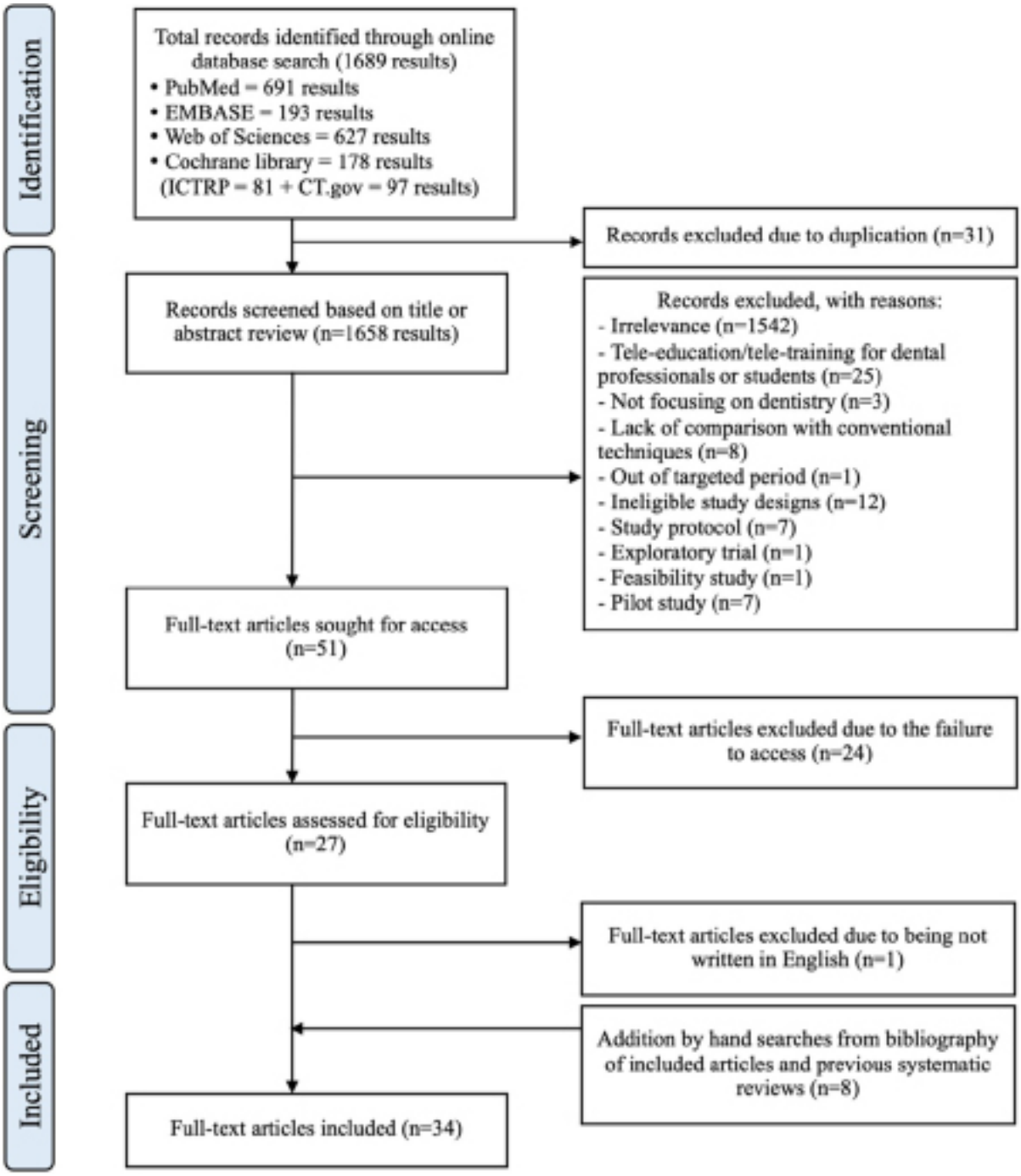

Figure 1. PRISMA flowchart: This diagram illustrates the methodological procedure used to incorporate publications in the systematic review of teledentistry (2011–2021).

Table 2. Different outcomes measure of included studies

Outcome measures	Orthodontic Dentistry	Preventive Dentistry	Pediatric Dentistry	Oral and Maxillofacial Surgery	Total number of studies
Clinical Indices	13	5	3	3	24
KAP	1	0	1	0	2
Clinical Indices & KAP	1	2	0	0	3
Clinical Indices and behavior modification	1	2	0	0	3
Behavior modifications and KAP	0	0	1	0	1
Cost and satisfaction	0	0	0	1	1

KAP refers to the knowledge, attitude, and practice of the participants. Detailed outcome measures are reported in Table 1.

dentistry. Studies predominantly emphasized three key areas: clinical indices, oral health knowledge and behaviors, and overall clinical effectiveness.

3.2.1. Orthodontic Dentistry

Most studies indicate that a combined approach of teledentistry and in-person dental practices can enhance oral health outcomes for orthodontic treatment. Digital health technologies, including mobile applications, SMS notifications, telephone communications, and specialized software, have proven effective for patient appointment reminders and engagement. A significant number of orthodontic studies (nine in total) advocate for this integrated approach to improve the oral health of orthodontic patients. While four studies demonstrated that teledentistry outperformed in-person dentistry in enhancing oral hygiene, two studies found no significant difference between the two approaches. Regarding outcome measures, clinical indices such as plaque index, gingival index, and bleeding on probing are predominantly used according to the study. Many studies utilized clinical indices and assessments of patient knowledge or evaluations of behavioral modifications. It's worth noting that one study employed a Knowledge, Attitude, and Practice (KAP) assessment as an outcome measure. The methodologies and findings underscore the evolving nature of teledentistry applications in orthodontic care.

3.2.2. Preventive Dentistry

This systematic review reveals that preventive dentistry is the second most prevalent field for teledentistry applications. Integrating teledentistry with in-person dental practices shows considerable promise. While some research suggests that both are comparably effective, other studies argue that teledentistry demonstrates superior outcomes. Notably, teledentistry has shown efficacy in disseminating oral health education within high school settings. Similar to the studies in orthodontics, clinical indices are predominantly utilized as primary outcome measures. However, a more comprehensive approach is often adopted, combining these clinical indices with assessments of patient knowledge or evaluations of behavioral modifications. This provides a more holistic understanding of teledentistry's impact on preventive dental care, encompassing both clinical outcomes and patient-centered factors.

3.2.3. Pediatric Dentistry

Three studies advocate for an integrated approach that combines teledentistry with conventional methods. However, two additional studies propose that teledentistry alone may offer superior outcomes in pediatric dental care. Regarding outcome measures, most pediatric dentistry studies rely on clinical indices as their primary evaluation tool. This approach aligns with the broader trend observed across dental specialties. Notably, two studies employ alternative assessment methods: one focuses on behavioral modification outcomes, while another utilizes the Knowledge, Attitude, and Practice (KAP) assessment.

3.2.4. Oral and Maxillofacial Surgery

Research in this area offers varied recommendations, reflecting the complex nature of surgical interventions. Some studies advocate for an integrated approach, combining teledentistry with in-person dentistry. Others propose that teledentistry alone can be sufficient. Conversely, some research supports in-person dentistry, particularly for oral health education in surgical contexts. The most common primary outcome measures are clinical indices. However, one notable study examines cost-effectiveness and patient satisfaction. This offers valuable insights into the economic and patient-centered aspects of teledentistry in surgical settings, providing a more comprehensive evaluation of its potential benefits and challenges.

3.3. Effectiveness of teledentistry compared to in-person dentistry

The analysis reveals that mobile health technologies emerged as the predominant communication method, closely followed by asynchronous techniques for remote patient monitoring. Interestingly, one study [17] combined both asynchronous and synchronous (real-time or live interaction) approaches, though it's worth noting that no research employed synchronous techniques exclusively. The application of teledentistry varied across the reviewed literature. While most studies implemented teledentistry as a complementary tool for oral hygiene instruction, education, and behavioral reminders, three studies explored its potential in different contexts. Specifically, these studies utilized teledentistry as an adjunct to physical exercises [19], professional consultation [6], and behavioral therapy [45].

3.4. Teledentistry usage according to income economy

The current review examined teledentistry adoption across 21 nations, as illustrated in Table 3, reveals a distinct pattern of implementation correlated with economic status. High-income countries demonstrate a well-established integration of teledentistry services into their healthcare systems. The review also identifies an emerging trend in upper-middle and lower-middle-income countries, where teledentistry utilization is gaining momentum and showing significant growth. However, there was no data on teledentistry utilization available from

low-income countries in the current review.

3.5. Quality assessment results

An evaluation of 34 teledentistry studies using the Downs and Black checklist revealed varied quality levels (). While nearly half (47.1%) of the studies were rated as good quality, about one-fifth (20.5%) were considered poor, and none achieved excellent quality. Most of the articles demonstrated high standards in reporting quality. However, specific methodological concerns were identified in two studies: one lacked external validity [10], potentially limiting the generalizability of its findings, while another exhibited a high risk of internal validity [43], which may affect the reliability of its results. Notably, over two-thirds of the studies had sufficient statistical power to detect treatment effects, indicating appropriate sample sizes and analyses to support their conclusions. This assessment provides a crucial context for interpreting teledentistry research, highlighting strengths and weaknesses. It offers valuable insights into the overall quality of evidence.

4. Discussion

This systematic review reveals the potential of teledentistry to complement and, in some cases, better than in-person dentistry in terms of efficacy and accessibility, particularly in oral health education, behavioral modification, and reinforcement. However, it is not yet being utilized for tele-treatment. Orthodontics employed teledentistry most commonly, followed by preventive dentistry, pediatric dentistry, and oral and maxillofacial surgery. Most studies found that integrating teledentistry with in-person dentistry improved patient outcomes. Mobile health technologies and asynchronous communication emerged as the most common teledentistry approaches. While the quality of the studies was good, some lacked robust design. Teledentistry shows promise in enhancing dental care, especially when used alongside in-person dentistry. High-income nations have well-established teledentistry services, while middle-income countries are increasingly adopting these technologies. However, there was a lack of data on teledentistry in low-income countries.

4.1. Field of Teledentistry

Teledentistry has demonstrated applications across dental specialties, with orthodontics emerging as the primary field of utilization. Research shows that integrating teledentistry with traditional practices significantly enhances oral health outcomes. Digital health technologies, including mobile applications and SMS notifications, have effectively improved patient engagement and appointment management. Teledentistry has proven particularly effective in disseminating oral health education in high school settings. Across specialties, clinical indices serve as the primary outcome measures, often complemented by assessments of patient knowledge, behavioral changes, and unique evaluations such as Knowledge, Attitude, and Practice (KAP) assessments and cost-effectiveness analyses. This comprehensive approach provides a more holistic understanding of teledentistry's impact, highlighting its potential to revolutionize dental care across various specialties. While existing studies have predominantly focused on teledentistry's role in health education and behavior modification, it is high time to broaden the research scope. Future investigations should explore its potential in professional consultations and diagnostic processes, areas that remain underexplored but offer significant potential for enhancing remote dental care delivery.

4.2. Effectiveness of Teledentistry

Teledentistry was found to be effective in improving patient education and behavior modification across various dental specialties. It also has the potential to enhance professional communication and may offer cost-effective solutions in certain scenarios. However, the effectiveness can vary depending on the specific application and dental specialty, highlighting the need for continued research and evaluation in this evolving field. As a recent advancement, evidence suggests that remote monitoring AI (artificial intelligence) system applications in orthodontics have become significant, driven by technological advancements and increased patient demands [47].

4.2.1. Patient education

Teledentistry has shown significant promise in enhancing patient education across various dental specialties. In orthodontics and preventive dentistry, digital health technologies such as mobile applications and SMS notifications have proven effective in disseminating oral health information [1, 48]. Notably, teledentistry has demonstrated efficacy in providing oral health education within high school settings [40]. The use of these technologies allows for consistent and accessible educational content, potentially improving patients' understanding of their oral health needs and treatment processes.

4.2.2. Behavior modification

The implementation of teledentistry has shown positive results in modifying patient behaviors. Several studies incorporated assessments of behavioral modifications as outcome measures, suggesting that teledentistry interventions can effectively encourage better oral hygiene practices with positive behavioral modifications [19]. For instance, in orthodontics, mobile applications and reminders have been associated with improved

Table 4. Quality assessment result of included studies

Article No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Reporting	5	7	6	9	6	9	8	5	9	6	6	10	7	8	9	6	6	9	10	9	7	10	8	9	10	9	10	10	8	10	10	8	9	10
External validity	1	0	1	1	1	1	3	1	2	1	1	2	1	1	2	1	1	1	1	1	1	2	2	0	2	2	1	3	3	1	2	2	3	1
Internal validity bias	1		4	5	5	5	4	4	5	6	[illegible]	5	5	5	5	4	5	6	6	1	[illegible]	[illegible]	4	4	6	6	7	6	[illegible]	5	5	5	5	5
Internal validity confounding (selection bias)	1	3	1	3	5	5	3	3	4	3	3	[illegible]	3		4	1	3	5	[illegible]	3	3	5	5	4	6	6	[illegible]	[illegible]	4	4	5	4	4	3
Power	0	[illegible]	0	0	1	1	[illegible]	0	[illegible]	1	0	1	[illegible]	0	[illegible]	0	0	1	0	1	[illegible]	[illegible]	[illegible]	1	1	0	1	1	2	[illegible]	1	1	1	1
Overall Score	13	15	17	18	16	20	17	10	23	16	18	22	15	17	21	[illegible]	[illegible]	25	[illegible]	18	19	25	20	18	25	24	22	24	20	22	25	30	25	14
Quality	*	**	*	**	**	‡	**	*	*	**	**	‡	**	*	*	**	**	‡	‡	**	**	*	**	**	‡	‡	‡	‡	*	*	‡	‡	‡	**

‡ Good quality, ** Fair quality, * Poor quality, [excellent (26–28); good (20–25); fair (15–19); and poor (≤14)]

oral hygiene among patients with fixed appliances. This indicates that teledentistry can be a valuable tool for reinforcing positive oral health behaviors between in-person visits.

4.2.3. Professional communication

Teledentistry has shown potential implications for professional communication. Teledentistry is recognized as a supervision tool connecting specialists with general dentists to minimize referrals [1,48]. This suggests that teledentistry can facilitate improved communication and collaboration between dental professionals, potentially leading to more efficient patient care and reduced unnecessary referrals [17]. In fields like oral and maxillofacial surgery, where some studies supported an integrated approach, teledentistry likely plays a role in enhancing communication between surgeons and other dental professionals involved in patient care.

4.2.4. Cost-effectiveness

There is limited direct information on cost-effectiveness, however, cost-effectiveness alongside patient satisfaction was also assessed. This might suggest that cost-effectiveness is an important consideration in teledentistry implementation. We can infer that teledentistry may offer cost-effective solutions in certain scenarios, such as reducing the need for in-person visits for routine check-ups or follow-ups, particularly in orthodontics and preventive dentistry. However, more research specifically focused on the economic aspects of teledentistry across different specialties would be beneficial.

4.3. Economic context

Teledentistry offers substantial economic benefits for the dental healthcare sector, providing potential cost and time savings compared to traditional in-person dentistry. This allows the management of more patients in less time

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[48], facilitating quick consultations and referrals [4], which translates to economic benefits for both dental practices and patients [4]. The adoption of teledentistry is progressing globally, but its integration varies considerably based on a country's economic resources and healthcare infrastructure. This variation highlights teledentistry's potential to bridge healthcare gaps across diverse economic landscapes. However, the review uncovered a significant data gap regarding teledentistry implementation in low-income countries, raising important questions about global health equity. This disparity underscores the need for further research and exploration of opportunities for teledentistry expansion in resource-limited settings. By addressing these gaps, teledentistry could play a crucial role in improving access to dental care and reducing healthcare disparities worldwide. Teledentistry offers significant advantages on an individual level, reducing out-of-pocket expenses and minimizing time off work. However, its implementation necessitates initial investments in technology—such as intraoral cameras, imaging systems, and reliable internet connections and training for healthcare professionals [49-51]. While these upfront costs are substantial, they may yield long-term economic benefits through improved efficiency and expanded reach, particularly in serving underserved populations. Integrating teledentistry with broader healthcare systems could further enhance economic efficiencies by reducing redundancies and improving coordinated care. The COVID-19 pandemic has highlighted teledentistry's potential to provide economic resilience during health crises [3,52]. Although specific figures are not provided, the study suggests that teledentistry has the potential for positive economic impacts through cost savings, improved efficiency, and better resource allocation in dental care delivery [6]. Realizing these economic benefits, however, requires addressing implementation challenges and carefully balancing initial investments against long-term gains. As teledentistry continues to evolve, its economic impact on both individual patients and healthcare systems at large promises to be significant, potentially reshaping the landscape of dental care delivery.

4.4. Evaluation of the risk of bias and limitations of this systematic review

The quality assessment of the studies suggests that while the field has a solid foundation of research, there's significant room for improvement in research methodologies. Most studies excelled in reporting standards and statistical power, indicating strong documentation practices and appropriate sample sizes. However, specific methodological concerns were identified in some studies, particularly regarding external and internal validity. These issues potentially limit the generalizability and reliability of certain findings. Despite these challenges, it provides valuable insights into teledentistry, offering a foundation for future research. It highlights both strengths (good reporting, sufficient statistical power in many studies) and weaknesses (lack of excellent-quality studies, some methodological issues) in the current literature. While this analysis provides valuable insights into the current state of teledentistry research across various dental specialties, there are limitations to consider, including the lack of consideration for specialty areas of dentistry, or specified dental treatment, limited consideration for teledentistry approach and the exclusion of non-English literature. Advancing teledentistry, it is important to focus on improving the quality and precision of research methods in future studies. This emphasis on excellence in research quality is crucial for strengthening the evidence base and improving the applicability of teledentistry findings. Future research endeavors should be multifaceted encompassing an exploration of teledentistry applications in specific dental fields, promotion of targeted treatment areas utilizing teledentistry, and maintenance of oral hygiene control. A crucial aspect to prioritize in the future is the incorporation and assessment of AI-driven remote monitoring systems in different fields of dentistry. Studies should utilize more robust designs, including larger sample sizes, and conduct longer follow-up periods to strengthen the evidentiary foundation for teledentistry. This synergy in the technology has the potential to transform into better remote dental care delivery and patient monitoring.

5. Conclusion

Teledentistry shows promise across dental specialties, particularly in orthodontics, for patient education and behavior modification. It offers potential cost and time savings but faces implementation challenges. Adoption of teledentistry varies by country's income level. Integration with traditional in-person care is beneficial. Future research should focus on long-term outcomes, patient satisfaction, and economic impacts globally.

Author Contributions

The study framework was conceived and designed by RK and HORK and HO conceived and designed the study framework (Hiroshi Ogawa). TH and BP conducted a thorough search for scientific literature and evaluated the risk of bias, with under the guidance of RK and the assistance of TZ. The interpretation of the results was performed by RK, TH, TZ, and HO (Hikaru Okubo) interpreted the results. The manuscript was written primarily by TZ, with TH's contributions from TH. RK, KMT, ST, and

HO (Hiroshi Ogawa) checked and approved the final manuscript. All authors provided constructive feedback and contributed to the development of the research, data synthesis, and manuscript preparation.

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Conflict of interest

Authors declare that there is no conflict of inerests.

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Tin Zar Tun, born on April 2, 1988, in Myanmar, is a dedicated doctoral student at Niigata University, Japan, focusing on Preventive Dentistry in the Graduate School of Medical and Dental Sciences. She has a robust research portfolio, co-authoring significant publications, including a systematic review on school-based oral health programs in PLOS ONE and a study on the 8020 Campaign's impact in Japan in the International Journal of Environmental Research and Public Health. Her work on teledentistry in oral health services has gained FDI's recognition from FDI. Recently, she investigated risks related to early childhood caries and the effectiveness of fluoride varnish in preventing dental issues. Currently, her research focuses on the oral function of older adults in Japan, contributing valuable insights to the field.

Questions

1. What are common technologies used in teledentistry?
❑a. Live video consulting;
❑b. Email correspondence;
❑c. Remote monitoring devices;
❑d. Faxing patient records.

2. Which of the following can be considered a benefit of teledentistry?
❑a. Increased travel time for patients;
❑b. Improved access to dental care for remote areas;
❑c. Reduced need for in-person visits;
❑d. Limited appointment availability.

3. What type of services can be provided through teledentistry?
❑a. Orthodontic consultations;
❑b. Post-operative follow-ups;
❑c. Major surgical procedures;
❑d. Dental cleanings.

4. In teledentistry, what is essential for patient-provider interactions?
❑a. Confidentiality and data privacy;
❑b. High-speed internet only;
❑c. Mandatory in-person visits;
❑d. Physical tools like dental mirrors.