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TELEMEDICINE IN DENTISTRY: A PATHWAY FOR IMPROVING ORAL HEALTH OUTCOMES

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ABSTRACT

Oral health is an essential component of general well-being, yet significant disparities in access to dental services persist worldwide. Telemedicine, applied to dentistry as teledentistry, has emerged as a modern approach to overcome these barriers by integrating digital communication technologies into prevention, diagnosis, treatment planning, and follow-up. This scientific paper provides a narrative review of the current evidence on teledentistry, outlining its conceptual foundations, modalities of communication, and main clinical applications. Benefits highlighted in the literature include improved accessibility for underserved populations, cost-effectiveness, enhanced interdisciplinary collaboration, and increased patient engagement. During the COVID-19 pandemic, teledentistry played a pivotal role in ensuring continuity of dental care and accelerating the adoption of digital workflows. Despite these advantages, barriers such as limited technological infrastructure, lack of standardized legal frameworks, and variable acceptance by patients and professionals remain challenges to wider implementation. Future perspectives emphasize hybrid models of care that combine in-person visits with remote consultations, the integration of mobile health applications, and the use of artificial intelligence to support personalized oral healthcare.

Key words: teledentistry; telemedicine; oral health; digital dentistry; covid-19; hybrid models, etc.

1. INTRODUCTION

Oral health is an essential component of general health, directly influencing nutrition, speech, social interaction, and quality of life. Despite advances in dental medicine, inequalities in access to oral healthcare persist, particularly in underserved populations where geographical and socioeconomic barriers limit treatment accessibility [1].

The advent of digital health technologies has provided novel solutions to overcome such challenges. Telemedicine, defined as the use of information and communication technologies to deliver healthcare services remotely, has gained a significant role in modern medical practice. Its application in dentistry, known as *teledentistry*, encompasses synchronous video consultations, asynchronous data transfer (*store-and-forward*), digital imaging, and remote patient monitoring, which together facilitate prevention, diagnosis, treatment planning, and follow-up care [2].

Several studies have confirmed the effectiveness of teledentistry in enhancing early detection of oral diseases, improving patient education, and optimizing referral pathways [3]. It has also proven useful across various dental specialties, including orthodontics, oral medicine, prosthodontics, and periodontology, where remote assessment and interdisciplinary collaboration are crucial

[4].

The COVID-19 pandemic accelerated the adoption of telemedicine, demonstrating its importance for maintaining continuity of dental care while minimizing infection risks. As a result, teledentistry has evolved from a temporary alternative into a sustainable and complementary model of practice, contributing to improved accessibility, cost-effectiveness, and patient-centered care [5].

The aim of this study is to provide a comprehensive analysis of telemedicine in dentistry, with a particular focus on teledentistry as an emerging field of modern healthcare. The research intends to examine the theoretical foundations that support the integration of digital technologies into dental practice, as well as to investigate the main areas of clinical application, ranging from prevention and diagnosis to treatment planning and long-term patient monitoring.

At the same time, the study seeks to identify the benefits of teledentistry, including improved accessibility, cost-effectiveness, and enhanced patient engagement, while also addressing its current limitations and challenges, such as technological barriers, regulatory constraints, and issues of data security. By synthesizing available scientific evidence and highlighting recent innovations, the work ultimately aims to outline the future perspectives of teledentistry and to emphasize its potential contribution to a more equitable, efficient, and patient-centered model of oral healthcare delivery.

2. LITERATURE REVIEW

The integration of telemedicine into dentistry has been increasingly explored over the last three decades, reflecting the broader shift towards digital health transformation in medical sciences. The first documented applications of teledentistry appeared in the late 1980s and early 1990s, primarily in the United States military, where digital communication technologies were used to improve access to oral healthcare in remote areas [6]. Since then, the field has expanded rapidly, driven by advances in information technology, the development of intraoral imaging systems, and the widespread adoption of internet-based communication tools.

The term *teledentistry* is now used to encompass a wide variety of practices, ranging from live, real-time consultations to asynchronous data exchange, remote monitoring, and the use of artificial intelligence in diagnostic support [7]. Multiple studies have confirmed that teledentistry offers comparable diagnostic accuracy to traditional face-to-face assessments for conditions such as dental caries, oral lesions, and orthodontic malocclusions [8].

In addition to its diagnostic potential, teledentistry plays a critical role in prevention and health promotion. By providing remote education and tailored oral hygiene instructions, it supports patients in maintaining better self-care and enables dental professionals to monitor progress over time [9]. These applications are particularly relevant in communities with limited access to dental services, where teledentistry reduces disparities and improves equity in oral healthcare delivery.

A narrative literature review was conducted, analyzing peer-reviewed articles, systematic reviews, and relevant reports published between 2000 and 2024. Sources were retrieved from PubMed, Scopus, and Web of Science databases using keywords including *telemedicine, teledentistry, oral health, COVID-19, and digital dentistry*. Studies were selected based on their relevance to the theoretical background, clinical applications, and systemic impact of teledentistry.

2.1. Conceptual Foundations of Telemedicine and Teledentistry

Telemedicine has been broadly defined by the World Health Organization as “the delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies” [10]. Closely related is the term *telehealth*, which refers to a broader set of services that extend beyond clinical care and may include

health promotion, patient education, and administrative functions [11]. Within dentistry, the term *teledentistry* was introduced in the early 1990s and is generally used to describe the remote provision of dental care, consultation, education, and information exchange through electronic communication technologies [12].

The origins of teledentistry can be traced back to projects initiated by the U.S. Department of Defense in 1994, which aimed to evaluate how telecommunication technologies could improve access to oral health services among military personnel [13]. Since then, technological progress—including the development of digital radiography, intraoral cameras, and broadband internet—has significantly expanded the scope of teledentistry. Initially limited to pilot projects, it has evolved into a recognized model of care in both public health and private dental practice [14].

The conceptual framework of teledentistry is grounded in several principles. First, it relies on the concept of patient-centered care, aiming to improve accessibility and equity in oral healthcare delivery. Second, it is based on the principle of technology-mediated communication, which enables real-time (synchronous) or delayed (asynchronous) interaction between professionals and patients. Third, it incorporates the principle of collaborative care, facilitating interdisciplinary communication between dentists, specialists, and allied healthcare providers. Finally, teledentistry aligns with the broader theoretical models of digital health, emphasizing efficiency, scalability, and sustainability in healthcare systems [15].

2.2. Modalities and Technologies in Teledentistry

Teledentistry is generally categorized into two primary modalities of communication: synchronous and asynchronous. *Synchronous communication* involves real-time interaction between patient and clinician or between professionals, most commonly through live video conferencing platforms [16]. This approach is valuable for remote consultations, emergency triage, and multidisciplinary case discussions. In contrast, *asynchronous communication*—often termed *store-and-forward*—relies on the transmission of clinical data (such as digital images, radiographs, or intraoral scans) that can be reviewed by the specialist at a later time [17]. This modality is highly efficient in reducing costs and overcoming scheduling barriers, and it is particularly effective for diagnostic screening and second opinions [18].

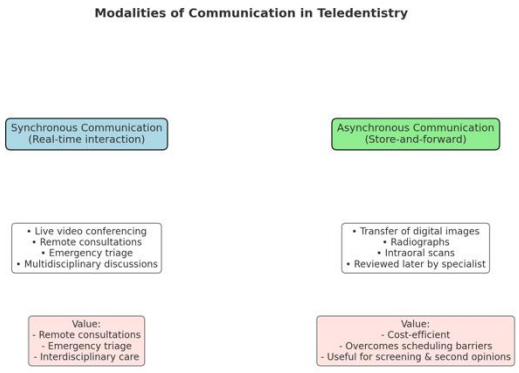


Figure 1- Modalities of Communication in Teledentistry

Technological innovations have greatly expanded the capabilities of teledentistry. Intraoral scanners allow the capture of high-resolution digital impressions, which can be transmitted electronically to dental laboratories or specialists for treatment planning [19].

Three-dimensional (3D) imaging, including cone-beam computed tomography (CBCT), enhances diagnostic precision in endodontics, implantology, and oral surgery when integrated into remote consultations [20]. CAD/CAM systems further support a fully digital workflow by enabling the design and

fabrication of dental restorations from digitally acquired data, reducing turnaround times and improving accuracy [21]. Mobile applications are increasingly employed to support patient education, post-operative monitoring, and communication between dental professionals and patients [22].

The successful implementation of teledentistry depends on robust digital platforms and adequate infrastructure. Secure platforms must comply with data protection standards such as HIPAA in the United States or GDPR in the European Union, ensuring patient confidentiality and legal compliance [23]. Cloud-based storage solutions allow the safe transmission and archiving of digital data, while interoperability standards are necessary to integrate teledentistry systems with existing electronic health records [24]. High-speed internet connectivity, portable imaging devices, and user-friendly interfaces are essential to ensure feasibility in diverse clinical environments, particularly in underserved or rural areas [25].

2.3. Clinical Applications of Teledentistry

One of the most important applications of teledentistry lies in the area of prevention and patient education. Through digital platforms and mobile applications, dentists can provide instructions for oral hygiene, dietary counseling, and behavioral modification, which are essential for reducing the incidence of dental caries and periodontal disease [26]. Remote educational interventions have been shown to increase patients' knowledge and motivation, particularly among children and adolescents, and are considered cost-effective public health strategies [27].

Teledentistry facilitates remote diagnosis and triage, enabling clinicians to assess oral health conditions from a distance using intraoral photographs, radiographs, or video examinations. This approach has proven particularly useful in rural or underserved communities, where access to dental clinics is limited [28]. Remote triage supports timely decision-making, ensures that urgent cases are referred to appropriate specialists, and reduces unnecessary in-office visits [29].

Teledentistry has been successfully integrated into multiple branches of dentistry. In orthodontics, it enables remote monitoring of treatment progress and appliance adjustments, thereby reducing the frequency of in-office appointments [30]. In prosthodontics, intraoral scans and digital impressions can be transmitted to laboratories or specialists for treatment planning and fabrication of restorations [31]. In periodontology, teledentistry aids in the detection of gingival and periodontal pathologies, while also supporting patient compliance through follow-up reminders and digital check-ups [32]. Oral surgery has also benefited, with postoperative evaluations being conducted via digital platforms, reducing the need for patients to travel long distances [33]. In pediatric dentistry, teledentistry supports early screening, parental education, and caries prevention programs [34].

Teledentistry is equally valuable in long-term monitoring and follow-up. Patients undergoing complex treatments, such as implant rehabilitation or orthodontic therapy, can be remotely monitored through regular submission of digital images and questionnaires [35].

This approach enhances continuity of care, strengthens communication between the patient and the dental team, and has been associated with improved treatment outcomes and higher patient satisfaction [36].

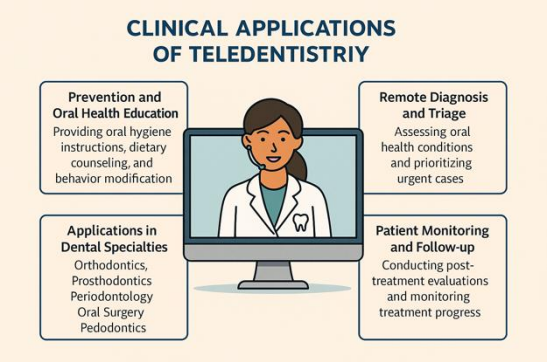


*Figure 2 -Clinical applications of teledentistr*2.4. *Benefits of Teledentistry Reported in the Literature*

The adoption of teledentistry has been consistently associated with significant benefits across clinical, social, and economic dimensions.

Improved access to care

One of the most frequently cited advantages of teledentistry is the improvement of access to oral healthcare in rural and underserved areas, where the number of dental professionals is limited. By enabling remote consultations, screenings, and follow-up appointments, teledentistry reduces geographic disparities and ensures that patients who otherwise would not have received timely care can benefit from professional guidance [37].

Cost-effectiveness

Teledentistry has also been shown to be cost-effective, both for healthcare systems and for patients. From the provider's perspective, it reduces unnecessary in-office visits, optimizes the allocation of clinical resources, and lowers indirect costs associated with staff and infrastructure [38]. For patients, savings derive from reduced travel expenses, less time off work, and quicker access to treatment [39].

Enhanced interdisciplinary collaboration

Another benefit lies in the facilitation of communication between dental professionals and specialists. Using digital platforms, general practitioners can share patient data with orthodontists, prosthodontists, oral surgeons, or periodontists, obtaining rapid second opinions and integrated treatment plans [40]. This fosters a more collaborative approach to care and improves diagnostic accuracy.

Patient engagement and compliance

Teledentistry supports patient education, motivation, and treatment adherence. Remote feedback, reminders, and digital follow-up tools have been associated with higher compliance rates in oral hygiene routines and orthodontic or periodontal therapies [41]. This active involvement of patients contributes to better long-term outcomes.

High levels of satisfaction

Studies consistently report that both patients and providers express high levels of satisfaction with teledentistry. Patients value its convenience, reduced waiting times, and the possibility to access professional advice without the stress of travel, while dentists appreciate the flexibility and the ability to expand their services to broader populations [42].

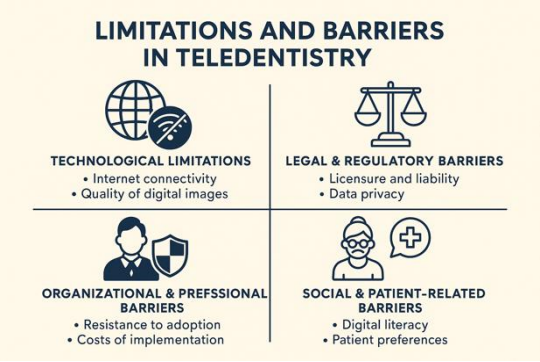
2.5. Limitations and Barriers

Despite the multiple benefits reported in the literature, the widespread implementation of teledentistry is hindered by several limitations and barriers, which can be grouped into technological, legal, organizational, and social domains.

A fundamental challenge in teledentistry is the dependence on adequate technological infrastructure. Limited internet connectivity, insufficient bandwidth, and inadequate access to digital devices compromise the quality of remote consultations, especially in rural or low-income settings [43]. Moreover, the diagnostic accuracy of teledentistry depends heavily on the quality of digital images, radiographs, and intraoral scans provided by patients or primary care providers [44].

Resistance among dental professionals also limits the integration of teledentistry. Some practitioners express concerns about reduced clinical control, insufficient training in digital technologies, or a perceived decrease in the quality of the dentist–patient relationship [47]. Additionally, implementation requires significant investment in equipment, training, and software, which may be difficult to justify for small dental practices [48].

From the patient's perspective, digital literacy and access to technology remain major obstacles. Elderly patients and individuals from disadvantaged communities often have limited ability to use telehealth tools effectively [49]. Furthermore, some patients prefer face-to-face interactions and may perceive remote consultations as impersonal or inadequate for their needs [50].



2.6. Telemedicine in Dentistry During the COVID-19 Pandemic

The COVID-19 pandemic, declared in early 2020, had a profound impact on the delivery of oral healthcare worldwide. During the periods of lockdown and social distancing, many dental practices were forced to suspend routine services, limiting care to emergency procedures only. In this context, teledentistry emerged as a critical tool for maintaining continuity of care [51].

Through video consultations and asynchronous communication, patients were able to receive professional advice, reassurance, and guidance for self-management of minor conditions while urgent cases were appropriately triaged to in-person visits [52]. This approach reduced unnecessary exposure and minimized the risk of viral transmission.

The pandemic also accelerated the integration of digital tools into daily clinical workflows. Dentists adapted by incorporating teledentistry for initial consultations, pre-treatment assessments, and postoperative follow-up [53]. In orthodontics, for example, remote monitoring applications allowed patients to upload digital photographs for evaluation, significantly reducing the need for face-to-face appointments [54]. In oral surgery and periodontology, teledentistry was used for follow-up evaluations and monitoring of wound healing, thereby reducing the burden on clinics and hospitals [55]. Such adaptations demonstrated the flexibility of digital health solutions in preserving access to care during periods of crisis.

The experience of the COVID-19 pandemic provided valuable lessons regarding the potential of teledentistry to complement traditional dental services. It highlighted the importance of preparedness, adaptability, and the rapid deployment of digital platforms in times of public health emergencies [56]. Beyond the pandemic, many professionals recognized that teledentistry should not be viewed as a temporary substitute but as a long-term adjunct to conventional practice [57]. The crisis thus acted as a catalyst for a broader paradigm shift towards hybrid models of care that combine in-person and remote approaches, enhancing both efficiency and patient-centeredness [58].

Figure 3 -limitations and barriers in teledentistry

3. FUTURE PERSPECTIVES

Future perspectives in teledentistry are closely linked with the development of artificial intelligence (AI) and big data analytics. AI-driven algorithms can support early detection of dental caries, periodontal disease, and oral cancer by analysing digital images and radiographs uploaded by patients or general practitioners [59].

Machine learning models also hold promise for predicting treatment outcomes and personalizing oral healthcare strategies.

The use of virtual reality (VR) and augmented reality (AR) is expected to enhance both clinical practice and dental education. These technologies can provide immersive platforms for remote training, surgical simulations, and patient education, thereby improving professional skills and patient understanding of treatment procedures.

When integrated with teledentistry, AR can facilitate real-time guidance during complex procedures performed in remote settings.

A paradigm shift towards hybrid models of dental care represents one of the most significant long-term consequences of the digital transformation in healthcare. Rather than positioning teledentistry as a substitute for conventional practice, this approach redefines it as a complementary component within an integrated system of oral health delivery.

Hybrid models balance the irreplaceable value of in-person visits, necessary for procedures such as restorative interventions, surgical treatments, and complex diagnostics, with the flexibility of remote interactions that support preventive strategies, triage, patient

education, and post-treatment monitoring.

The adoption of such models allows for a more efficient allocation of clinical resources, ensuring that chairside time is reserved for interventions that require direct professional expertise, while routine counseling and follow-up can be managed digitally. This not only reduces patient waiting times and clinic congestion but also optimizes workflow and resource utilization for practitioners. Furthermore, hybrid models enhance continuity of care: by maintaining regular contact with patients through digital platforms between physical appointments, dentists can identify emerging problems earlier and intervene more effectively.

From a systemic perspective, hybrid dental care aligns with the broader reforms currently shaping healthcare worldwide, which place emphasis on accessibility, equity, and cost-effectiveness. By reducing the burden of unnecessary in-office visits, these models contribute to sustainability, lowering environmental impact through reduced travel, minimizing costs for patients, and improving the scalability of services in resource-limited settings. Consequently, hybrid models are increasingly viewed not merely as a response to extraordinary circumstances such as the COVID-19 pandemic, but as a durable and future-oriented framework for modern dentistry.

Mobile technologies are expected to remain central to the expansion of teledentistry, particularly through the use of smartphone-based platforms. These tools extend dental care beyond the clinical environment, offering patients the possibility to engage in self-monitoring of their oral health status, record symptoms, and track daily hygiene practices.

By facilitating behavioral interventions—such as reminders for toothbrushing, dietary guidance, or adherence to orthodontic instructions—mobile applications encourage greater patient compliance and foster a sense of responsibility in maintaining oral health.

A distinct advantage of mobile platforms lies in their capacity to provide real-time feedback. Patients can upload photographs, video recordings, or data from intraoral sensors, which are then rapidly assessed by dental professionals. This immediacy supports early identification of potential issues and enables timely professional advice, reducing the risk of complications and improving treatment outcomes. The interactive nature of mobile applications also enhances patient engagement by transforming passive recipients of care into active partners in the therapeutic process.

Furthermore, integration with wearable devices and cloud-based systems strengthens the potential for continuous, personalized monitoring. Smartwatches and oral health sensors, when linked to digital records, allow the collection of longitudinal data on patient behavior, treatment progress, and risk factors. Cloud technology ensures that this information is securely stored, easily accessible to both patients and professionals, and shareable within interdisciplinary care teams. Together, these innovations point towards a model of dentistry in which mobile health technologies function not only as adjunctive tools but as essential components of personalized, patient-centred oral healthcare.

Finally, the expansion of teledentistry will require supportive policies, training curricula, and international collaboration. Professional education must incorporate competencies in telehealth, data security, and digital literacy to prepare future practitioners. On a broader scale, teledentistry is expected to contribute to global oral health initiatives by reducing inequalities and supporting sustainable development goals related to universal health coverage.

4. CONCLUSIONS

- Teledentistry has emerged as a valuable component of modern dental practice, providing innovative solutions to overcome barriers in access to oral healthcare. Evidence from the literature highlights its capacity to improve accessibility for underserved populations, reduce costs, and support prevention, diagnosis, and long-term monitoring. Its successful application across specialties such as orthodontics, prosthodontics, periodontology, and pediatric dentistry confirms its versatility and clinical relevance.
- The COVID-19 pandemic accelerated the adoption of digital tools in dentistry, demonstrating the critical role of teledentistry in maintaining continuity of care under restrictive conditions.
- This experience emphasized the need to integrate digital approaches not only as emergency alternatives but as sustainable complements to conventional practice.
- However, significant barriers remain, including technological limitations, legal and regulatory uncertainties, and the need for greater digital literacy among both professionals and patients. Addressing these challenges is essential for the widespread adoption and long-term success of teledentistry.
- Looking forward, hybrid care models, integration of mobile health technologies, and the use of artificial intelligence are expected to reshape oral healthcare delivery.
- By aligning with global health goals of equity, efficiency, and sustainability, teledentistry represents a transformative pathway to improved oral health outcomes.

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