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Teledentistry and oral health in older adults — aspects for implementation of the “Patient centric solution for smart and sustainable healthcare (ACESO)” project

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Abstract: **Purpose:** Oral health and diseases are significant components of general health. However, oral health-care remains at the lowest of older patients’ priorities. The inability to obtain dental care can result in progression of dental disease, leading to a diminished quality of life and overall health. Teledentistry (TD) provides an opportunity to improve the quality of oral health services. The aim of our narrative review was to analyze the usefulness of teledentistry as a part of telemedicine to improve oral health in the elderly.

Materials/Methods: The PubMed database search was done for: teledentistry, oral health, oral-health related diseases, elderly, older adults.

Results: The applicability of TD has been demonstrated from children to older adults. Older adults have many obstacles in getting oral health care, including low income, lack health insurance, frailty, anxiety, depression, mobility problems or other handicaps. Available data suggests that the usefulness of TD in the provision of oral care in elderly people living in residential aged care facilities. Moreover, TD procedures were found to be as accurate as traditional face-to-face dental examinations, they was cost-effective and well accepted among patients and caregivers.

Conclusion: TD might be a very useful tool for professional education, improving access and patient satisfaction of dental care. However, such TD modes would be difficult to widely implementation in community-dwelling older people who cannot access dental care. The ongoing “Patient centric solution for smart and sustainable healthcare (ACESO)” project will add to the intelligent oral health solutions.



Keywords: teledentistry, older adults, oral health, oral health-related diseases.

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Introduction

Human life-span increased markedly over the past century [1]. However, longer life comes at a cost of chronic diseases, and geriatric syndromes. Geroprotectors (autophagy enhancers, senolytics, or specific drugs improving neurogenesis) hold some promise, however the time of translation from research to practice is long [2, 3]. Current anti-aging strategies focus on lifestyle interventions including regular exercise, proper diet, and age-related disease-prevention [3–6]. Despite the fact that nutrient-rich, calorie depleted diet may have beneficial effect in younger populations, in older adults with chronic diseases, disability or frailty, calorie restriction may reduce the immune defenses and the ability to heal wounds or fractures [7, 8]. Unfortunately, the physical, physiological, psychosocial, and emotional characteristics of older age predispose to poor nutrition with negative impact on disease outcome [9, 10]. Poor dentition significantly adds to the problem [9, 11].

Oral health, which includes dental caries, periodontal disease, tooth loss, oral cancer, oral manifestations of infections, oro-dental trauma, and birth defects, is an important part of overall health and quality of life [12, 13]. Effective health promotion and intervention programs for improving oral health are needed, as an estimated 3.5 billion people worldwide have problems with dentition, which has especially grave consequences in older persons [14–18].

Data from the American Dental Association indicate that older adults, while suffering from easily treatable conditions have not visited the dentist in more than 12 months because of cost, perceiving no need for a visit since they have none of their original teeth, fear of the dentist, and trouble finding an accessible dentist with convenient appointment times [19]. The inability to obtain dental care can result in the progression of dental disease, leading to a diminished quality of life and overall health. Additionally, older adults are often unable to afford dental care because of decreased mobility, lack of accessibility to health-care services, poor health literacy, high or unaffordable costs of dental treatments, and long distances from specialists. Teledentistry (TD) give an easy possibility to address these barriers and to improve the quality of oral health services. The aim of our narrative review was to analyze usefulness of teledentistry as a part of telemedicine to improve oral health in the older population and possibilities to wider implementation that form of telecare in the older, often disabled patients.

Methods

Data are based on the results of original and review articles relating to teledentistry and oral health especially in the older population, and analyze the possibilities how teledentistry interventions are able to influence the general health of older patients. To this end we used the PubMed database. The following keywords were searched: teledentistry, oral health, oral-health related diseases, elderly, older adults. Then we selected the most relevant full texts and reviewed the articles. Our review includes only human studies published in English.

Use of teledentistry in dental public health services

TD is a relatively new branch of telemedicine that is dedicated to dentistry, the use of which increased significantly due to the onset of the COVID-19 pandemic. TD is a combination of telecommunication technology and dental care. It delivers dental services through interactive audio, video, or other electronic media for the purpose of diagnosis, consultation, treatment or transfer of dental information [20]. TD uses information and communication technology for oral care, counseling, education, and public awareness to improve oral health [21]. It is especially dedicated for people who cannot for various reasons seek proper oral care and dental treatment.

Recently, an integrative review of 24 studies was published that reported original data related to the use of TD in public dental health services [22]. Da Costa *et al.* found that TD might be a very useful tool for improving access and patient satisfaction of dental care, and professional education. The significant aspect of TD application is tele-education in dental public health services, which may help to provide diagnoses and recommend treatments over long distances. Improvement in the knowledge of professionals by tele-education may facilitate the detection of caries, cancer, and periodontal disease and other oral problems. The applicability of TD has been demonstrated from children to older adults and among orthodontic patients and prisoners [20, 23–26]. Moreover, patients have the possibility to follow-up with their dentists online. TD, through promoting preventive strategies, may potentially influence morbidity and mortality.

Finally, TD has potential utility in more complex forms of dental treatment requiring the cooperation of multidisciplinary teams [22].

The benefits of TD in public health services are connected with the improvement and dissemination of knowledge among dental practitioners by using tele-education and tele-assistance applications [22]. The use of TD reduces the time to diagnosis and initiation of treatment among different groups of patients and improves communication between dentists and their patients. TD also allows for easy consultations with specialists. Moreover, a reduction in costs by about 30% was documented when compared with traditional forms of treatment.

Obstacles of TD are related to low levels of motivation and poor compliance, limited information technology skills, technological requirements, a lack of a network between TD applications and limitations, legal issues, and insurance barriers [22]. Another challenge is the ability to accurately perform evaluations of oral disease by nonoral health professionals (e.g. nurses).

Oral health problems in older people to monitor in teledentistry

Analysis of national and regional data of oral health among community dwelling older adults revealed that there was a higher prevalence of oral diseases among older populations worldwide compared to younger age groups [27]. Tooth loss was more frequent in developed countries, but dental decay and periodontal disease are widespread globally. Poorer oral health was more commonly observed among older persons with dementia compared to those without cognitive impairment [28]. The worst situation was documented among residents of long term care facilities. A systematic review of 24 surveys reported that oral cleanliness and health of the surveyed institutionalized older persons were poor with low denture hygiene [29]. Population-based surveys in the United States and Germany demonstrated that the oral health of the aged adults has improved considerably during the last few decades, but a substantial burden of caries and periodontitis is still apparent for this group [17].

Dental caries remains a major oral health problem among the older population, mainly because of age-related salivary changes, poor diet, gingival recession with exposure of the root surface and xerostomia [9]. Caries is associated with tooth loss. However, current routine restoration procedures have changed; after removal of the least possible amount of decayed tooth, efforts are concentrated on remineralizing the affected tooth with fluoride, avoiding the need for removable or fixed prostheses [30].

The frequency of periodontal disease increases with age, but severe periodontitis seems to be fairly constant among the aged [31]. However, periodontal disease is associated with the accumulation of bacterial plaque with consequent gingivitis and mild or moderate alveolar bone loss and increased likelihood of tooth loss. Tooth loss increases morbidity and mortality risk. The number of remaining teeth was an independent predictor of all-cause mortality and mortality of cardiovascular disease and coronary heart disease in a Swedish cohort followed for 12 years [32]. Each missing tooth in persons from a Korean cohort during follow-up over 7.5 years was associated with an approximately 1% increase in myocardial infarction, 1.5% increase in heart failure and stroke and 2% increase in mortality rate [33]. However, signs of professional intervention, such as root canal fillings and removable dentures, appeared to be associated with improved survival in Finnish adults with a follow-up of about 8 years [34].

The final phase of caries and periodontal disease is tooth loss and eventually edentulism. Edentulism is related to mastication and nutritional problems and may be a good predictor of mortality [35]. Complete edentulism varies among countries with a prevalence of edentate older patients between 20–40% [36]. The problems of edentulism were mainly observed when mastication function was not reestablished with dental prostheses [9]. However, stomatitis and traumatic ulcer were prevalent among individuals with prostheses.

The frequency of salivary gland hypofunction and xerostomia has been shown in the older population [37]. The risk factors of xerostomia are advanced age, female gender, poor general health and polypharmacy. Dry mouth syndrome had an impact on the oral and general quality of life, so people with xerostomia require preventive measures against its consequences [9].

Oral cancer (comprising of lip, oral cavity, and pharyngeal cancers) is the eighth most common cancer worldwide [13]. The cancer and its treatment may cause major anatomical changes in the oral cavity with alteration of speaking, mastication or swallowing. Dental care before, during, and after treatment is necessary to maintain or improve the quality of life of oral cancer patients [9].

Systemic diseases and geriatric problems can negatively influence the general wellbeing and oral health of older patients which very often have oral manifestations and negatively impact oral health and dental treatment [38, 39]. The management of oral problems in patients with several systemic diseases is more complex and adverse effects of pharmacotherapy prescribed for chronic conditions may negatively influence the oral environment. Additionally, patient's disease-related handicap may reduce the ability to maintain adequate oral hygiene. Poor oral status may significantly contribute to an increased level of general morbidity and mortality. Periodontal disease is associated with diabetes and cardiovascular disease, but it may be also an independent risk factor for dementia, pulmonary infections, some types of cancer, and kidney disease [40, 41].

The relatively new aspect of poor oral health among the seniors is oral frailty and its association with the pathogenesis of frailty syndrome. The results of a longitudinal study demonstrated that poor status of oral conditions was a strong predictor of physical frailty, sarcopenia, the need for long-term care, and mortality in community-dwelling older individuals [42]. Oral status was diagnosed based on 6 measures: the number of natural teeth, chewing ability, articulatory oral motor skill, tongue pressure, subjective difficulty in eating tough foods, and subjective difficulty swallowing. Oral non-frailty was defined as not one of the six targeted measures being poor, oral prefrail status as poor status in 1 or 2 measures, and oral frailty status as poor status in 3 or more of the 6 targeting measures. Participants with oral frailty were significantly more likely to be older, with a lower level of education, yearly income, cognitive function, body mass index, serum albumin, and a higher prevalence of

physical frailty and sarcopenia at baseline, higher depressive score, and take more medications. However, no significant association was found between chronic conditions and oral frailty.

Utilization of teledentistry in the aged population

Older adults meet many obstacles in getting oral health care. Some of them forego dental care since they cannot afford it, due to low income or lack of health insurance. Moreover, health insurance often does not cover complete dental services. Older patients, who can afford dental treatment, frequently face other barriers. About one third have trouble getting to a dental office due to frailty, anxiety, depression, mobility problems or other handicaps [43].

TD offers opportunities to overcome these barriers [20]. It gives access to virtual consultations for frail and disabled patients and those who live in rural or outer-metropolitan areas. Such initial virtual consultations may help to overcome anxiety among those with significant dental fear and making it easier to arrange the physical appointment. Moreover, phone and video consultations improves emergency care. A recently published systematic review of papers assessing the feasibility of TD in the elderly people revealed that TD could be a practical tool for the management of oral care in people who cannot access dental care [44].

Marino *et al.* tested the technical feasibility and acceptance, by both users and residents, of an alternative model to the traditional face-to-face oral health examination using a TD installation [45]. Five trained intra-oral camera nurses recorded and transmit video images for the generation of treatment plans by qualified clinicians. Information from the remote examination was compared with a real-life dental examination. The data from 50 residents living in residential aged care facilities (RACF) in Australia were collected. Results indicated that the proposed TD method for oral health screening was feasible and reliable as an alternative to traditional oral health assessment. Moreover, residents expressed high levels of satisfaction with the TD service. The cost of the teleconsultation/telediagnosis presented no significant differences between real-time and the TD model.

The next article prepared by Marino *et al.* was mainly concentrated on a cost-analysis comparing the cost and benefits of face-to-face patient examination assessments conducted by a dentist at RACF with two TD approaches utilizing virtual oral examinations [46]. Real-time (synchronous) mode of TD included simultaneous transmission of oral examination images and consultation by oral health professionals remotely located. When the images of an oral examination were recorded and then transmitted to oral health professionals for subsequent review and build a treatment plan, the model of TD was called asynchronous. One hundred residents received an oral health assessment and treatment plan for each model. Results revealed that tele-

dental asynchronous patient assessments were the lower cost service model. However, the real-time consultation could potentially achieve better outcomes via health promotion and disease prevention information delivered simultaneously during the oral examination.

The objective of another study from Australia was to describe the development and implementation of another TD model in RACFs [47]. The model developed incorporated a visit by an oral health therapist (OHT) for screening, simple intervention and referral for a TD session if required. The TD appointment involved the OHT using an intraoral camera probe to transmit a live feed of the resident's mouth to a dentist. During the TD appointment, the dentist advised a treatment plan for the OHT and live images were transmitted and stored for later review. Of the 116 persons screened by OHT, 28% of residents required a TD review and 16% of residents required an in-person appointment at an oral health facility. Positive feedback was received from staff, residents and families (increased awareness of residents' oral health needs and prevention requirements). There were also potential financial and social cost savings for residents and the facilities in minimizing the need to transport a resident to an oral health facility.

The next step of the aforementioned project was to investigate the impact and experience of an integrated oral health program utilizing TD and OHT in RACFs [24]. A mixed methods comparative study was conducted to compare aged care facilities with and without access to the integrated oral health program incorporating visiting OHTs and TD. A total of 252 audits were completed, 111 from RACFs with an integrated model of oral health care and 144 without such a model. Audits showed an improved compliance to care quality accreditation standards for oral health in the facilities with access to the integrated program compared to those without the program. Facilities with the integrated program especially reported enhancements in the importance placed on oral health, better access to oral health services and training, and decreased disruption of residents, mainly those with high care needs.

The Tel-e-dent multicenter study was performed in nursing home residents in France and Germany [48]. The aim of the study was to evaluate the accuracy of TD for diagnosing dental pathology, assessing the rehabilitation status of dental prostheses, and evaluating chewing ability. In total 235 patients with oral or dental complaints were examined. A dental surgeon established the initial diagnosis by reviewing a video recorded in the nursing home and accessed remotely. The second examination was performed within a maximum of 7 days by the same surgeon who established the initial diagnosis. The sensitivity of TD for diagnosing dental pathology was 93.8% and the specificity was 94.2%. The sensitivity of TD for assessing chewing ability was 85.0%, and the specificity was 82.8%. The sensitivity of TD for assessing the rehabilitation status of dental prostheses was 87.8% and the specificity was 90.3%. The acceptability rate of TD (95.3%) among residents and their families was excellent.

The aim of the e-DENT pilot project was to provide the acceptability of the teleconsultation system using in 135 patients from long-term care facilities and a prison medical department in France [26]. The acceptance was assessed by observing how patients reacted during the teleconsultation procedure. Despite the complications caused by fear of dental treatment, and the fact that the use of an intraoral camera is an invasive procedure, the initial results indicated good acceptance in non-psychotic elderly patients, but psychotic patients presented a somewhat negative experience during the oral teleconsultation.

Available data suggests the usefulness of TD in the provision of oral care in elderly people living in residential aged care facilities [44].

Teledentistry modes and applications

TD cannot replace some oral health services, especially dental treatment. Sometimes a diagnosis cannot be made without complementary tests, which require equipment available only in dentists' practices. However, dental offices utilizing multiple digital solutions may offer some sort of virtual communication tool for announcements, reminders and education [9]. A pioneer project in TD was implemented for the first time by the United States army [49]. Since then TD has gradually developed and has observed a shift in technological advancement from the use of the telephone system, through the usage of fax machines, file transfer via satellite, integrated services digital network, to the world wide web [9].

TD is mainly the provision of patient care or education using one of four forms of technology:

- Synchronous mode, which offers live “real-time” video interaction between a health provider and a patient, a caregiver or another provider using telecommunications technology;
- Asynchronous mode gives possibilities through the transmission of photographs, video, X-rays or other recorded health information via a secure electronic system to a health provider. The health provider uses the information to evaluate a patient's condition and to prepare treatment plan without live interaction;
- Remote patient monitoring (RPM) allows the collection of personal health or medical data from a patient in a different location and the monitoring of a specific condition or vital sign;
- Mobile health (mHealth) uses smartphones, tablet computers, or other mobile devices to facilitate communication [50].

TD has many proven applications that can be implemented to increase access to care, provide safeguards, and create convenience for patients [51]. The first application is useful during a crisis or pandemic scenario to perform triage, screen, or

limited evaluation. It helps determine if a patient's needs are nonurgent or emergent. TD application may be also useful to control level of hygiene care as recall or preventive appointments. The further application allows for patient consultations with the dental team member or a more in-depth discussion about treatment plan options with the dentist. TD may be an important element in comprehensive community outreach programs. Those modes of care are most often implemented in school or nursing home settings and participants receive a complete examination and treatment plan and staff can be utilized more efficiently based on the needs of the patients [9]. Finally, TD helps health providers to transfer data to specialists for additional consultation [48].

The implementation of TD needs to requires searching for tools on the market that offer the best functionality to provide a seamless management of teledentistry patients [51]. TD tools most often offer only video conferencing and messaging capabilities to perform the visit but not the functionality to close the workflow cycle. Thus, there is a need to evaluate the technology's capabilities and patients' needs in order to find new ways to deliver care.

The ACESO project

The "Patient centric solution for smart and sustainable healthcare" (ACESO) project aims to leverage the use of artificial intelligence to create an integrated health and oral-care platform through the use of intelligent devices and data analytics, with the focus on xerostomia.

Sixty participants, 40% with xerostomia, aged ≥ 60 years, with varying states of dentition will be recruited in the pilot study, following classification based on a Comprehensive Geriatric Assessment. Participants' salivary status at rest as well as in function will be assessed using the lemon juice or citric acid challenge test to differentiate between patients with and without xerostomia. The individual components to assess the end-user's oral hygiene (smart toothbrush) and oral-hygienic behaviour will be tested together with devices measuring general health status (sphygmomanometer, thermometer, pulse oximeter, weighing scale, activity and sleep bracelet, and glucometer). Further, the platform integrating these components will be set-up and tested in all individuals giving input to the artificial intelligence (AI) training.

The results will inform the AI models to associate the seemingly disparate health and oral hygiene phenomena possibly indicating rapid changes in patients' health and wellbeing. The hitherto performed feasibility pilot, demonstrated that the adopted salivary secretion challenge is capable of differentiating patients into those with and without salivation problems.

Preliminary tests performed revealed that most cases responded well to chemical stimulation. However, some participants displayed decreased salivary flow due to

a decrease in parotid secretions. Further research is required to establish the basis of these findings.

The project will provide a platform for an integrated health assessment including the very important issue of the oral health.

Conclusions

Teledentistry offers an innovative ability for the delivery of better oral health care services to older people. TD services should continue develop to ensure the adoption of age-friendly services. Moreover, an effective translation of TD into clinical practice would ensure or improve access of oral health care to older adults in difficult-to-serve locations. The ongoing ACESO project will add to the intelligent oral health solutions.

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Conflict of interest

The authors are part of the AAL ACESO consortium.

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