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## Original Study

# Accuracy of Teledentistry for Diagnosing Dental Pathology Using Direct Examination as a Gold Standard: Results of the Tel-e-dent Study of Older Adults Living in Nursing Homes



Alain Queyroux MD<sup>a</sup>, Bernard Saricassapian MD<sup>b</sup>, Daniel Herzog MD<sup>c</sup>, Karin Müller MD<sup>d</sup>, Isabelle Herafa MSc<sup>e</sup>, Dorothée Ducoux MSc<sup>e</sup>, Benoît Marin MD, PhD<sup>f,g</sup>, Thierry Dantoine MD, PhD<sup>h,i</sup>, Pierre-Marie Preux MD, PhD<sup>f,g</sup>, Achille Tchalla MD, PhD<sup>h,i,\*</sup>

<sup>a</sup> ENT, Head and Neck Surgery Department, Guéret Hospital, Guéret, France

<sup>b</sup> Odontology–Dental Medicine Department, Guéret Hospital, Guéret, France

<sup>c</sup> Dental Care Clinic, Kassel District, Germany

<sup>d</sup> Department of Health, Kassel District, Germany

<sup>e</sup> CHU Limoges, Accompagnement de la Recherche Clinique Hospitalière (ARCH); INSERM U1435 Centre Investigation Clinique (CIC), Limoges, France

<sup>f</sup> Université de Limoges, INSERM, CHU, UMR\_S 1094, Institut d'Epidémiologie Neurologique et de Neurologie Tropicale, CNRS FR 3503 GEIST, 87000 Limoges, France

<sup>g</sup> CHU Limoges, Centre d'Epidémiologie de Biostatistique et de Méthodologie de la Recherche, Limoges, France

<sup>h</sup> Université de Limoges, CHU Limoges; EA 6310 HAVAE (Handicap Activité Vieillesse Autonomie et Environnement), IFR 145 GEIST; 87000 Limoges, France

<sup>i</sup> CHU Limoges, Pôle Clinique Médicale et Gériatrie Clinique, Service de Médecine Interne Gériatrique, Limoges, France

## A B S T R A C T

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**Importance:** Dental neglect and high levels of unmet dental needs are becoming increasingly prevalent among elderly residents of long-term care facilities, although frail, elderly, and dependent populations are the most in need of professional dental care. Little is known about the validity of teledentistry for diagnosing dental pathology in nursing home residents.

**Objectives:** To evaluate the accuracy of teledentistry for diagnosing dental pathology, assessing the rehabilitation status of dental prostheses, and evaluating the chewing ability of older adults living in nursing homes (using direct examination as a gold standard).

**Design:** Multicenter diagnostic accuracy study performed in France and Germany.

**Setting:** Eight nursing homes in France and Germany.

**Participants:** Nursing home residents with oral or dental complaints, self-reported or reported by caregivers, willing to receive oral or dental preventive care. In total, 235 patients were examined. The mean age was  $84.4 \pm 8.3$  years, and 59.1% of the subjects were female.

**Intervention:** The patients were examined twice. Each patient was his or her own control. First, the dental surgeon established a diagnosis by reviewing a video recorded in the nursing home and accessed remotely. Second, within a maximum of 7 days, patients were examined conventionally (face-to-face) by the same surgeon who established the initial diagnosis.

**Measurements:** All residents received a comprehensive clinical examination in their home by a trained geriatrician and underwent a dental hygiene evaluation that used the Silness-Loe and Greene-Vermillion dental hygiene assessment indices. The diagnoses established via the video recording and in the face-to-face setting were compared. The main outcome measure was number of dental pathologies.

**Results:** In total, 128 (55.4%) patients had a dental pathology. The sensitivity of teledentistry for diagnosing dental pathology was 93.8% (95% confidence interval [CI] 90.7–96.9), and the specificity was 94.2% (95% CI 91.2–97.2). Among the 128 cases of dental pathology identified by teledentistry, 6 (4.8%) were false positives. The teledentistry assessments were quicker than the face-to-face examinations (12 and 20 minutes, respectively).

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\* Address correspondence to Achille Tchalla, MD, PhD, Associate Professor in Geriatric Medicine, University of Limoges, CHU Limoges; IFR 145 GEIST; EA 6310 HAVAE (Handicap Activité Vieillesse Autonomie et Environnement), Limoges F-87025, France.

E-mail address: [Achille.tchalla@unilim.fr](mailto:Achille.tchalla@unilim.fr) (A. Tchalla).

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**Conclusions:** Teledentistry showed excellent accuracy for diagnosing dental pathology in older adults living in nursing homes; its use may allow more regular checkups to be carried out by dental professionals.

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The number of elderly people in nursing homes has dramatically increased in recent years, with approximately 19% of those aged 85 years and older living in such institutions in USA.<sup>1</sup> In a previous study, 65% of nursing home residents had oral health problems, and a high rate of poor oral health has been reported in this population by other studies.<sup>2</sup> However, it is unknown whether there are differences in the oral health status of residents according to race and ethnicity. Approximately 70% of elderly people can be classified as functionally independent, which in the present context may be defined as the capacity to visit the dentist regularly, whereas 14% are classified as frail (having chronic conditions that limit mobility or receiving palliative care that may lead to poor access to dental care).<sup>3</sup> Approximately 5% of elderly people are functionally dependent; this status is more typical of those who are institutionalized in nursing homes.<sup>1</sup> Approximately 72% of aging adults are classified as dentate, that is, with more than 18 natural teeth. These adults are at increased risk for periodontal and dental diseases, as well as diseases of the soft tissues and palate. Furthermore, chronic dental disease combined with systemic disease, which is more common in the elderly, may require more complex treatment protocols.<sup>4</sup> Poor oral health can negatively affect quality of life. Thus, oral health care is an important public health issue that must be addressed by policy makers. To this end, a previous study identified the following important long-term goals: to improve the quality of oral health care for, and overall health of, long-term care residents; prevent potential disease; foster these aims among long-term care facilities; and improve access to care.<sup>5</sup> Weight loss, chewing and communication problems, and increased risk for systemic illnesses (such as diabetes, ischemic heart disease, and chronic respiratory disease) have all been observed among elderly populations with dental problems.<sup>6,7</sup>

There have been extensive technological innovations in the field of dentistry in recent years. The most important advances have been made in the use of computers, telecommunications technology, digital diagnostic imaging services, and specialized hardware and software for patient screening and follow-up; capabilities that were considered out of reach 20 years ago are now a reality in dental care. By exploiting more advanced information technologies, the science of dentistry has recently progressed far more than it had during the previous 20 centuries. New information technologies have not only improved the quality of dental patient management but have also made it possible to achieve partial or complete management remotely, even at distances of thousands of kilometers from health care centers or dental practices.<sup>8</sup> Networking, the sharing of digital dentistry information, and distant consultations, workups, and analyses are handled by a specific branch of dentistry-related telemedicine known as teledentistry. To our knowledge, no study has evaluated the accuracy of teledentistry for diagnosing oral health disorders among elderly nursing home residents.

We hypothesized that teledentistry, as a diagnostic approach, would be as effective as face-to-face examinations. Teledentistry has numerous advantages, including rapid, documented, and remote consultations, as well as the possibility of simultaneous communication with multiple participants.

To test our hypothesis, we evaluated the accuracy of teledentistry for diagnosing dental pathology, assessing the rehabilitation status of dental prostheses, and evaluating the chewing ability of older adult residents of nursing homes, using direct examination as a gold standard.

## Materials and Methods

### Ethics Statement

This study was reviewed and approved by the Institutional Review Board of the University Hospital Centre of Limoges. The protocol was also reviewed and accepted by our local ethics committee and the Commission Nationale Informatique et Libertés (CNIL). Written informed consent was obtained from each participant before conducting any clinical or paraclinical examination. The study was conducted according to the principles of the Helsinki Declaration.

### Study Design

This was a 2-year, multicenter, cross-sectional study. Elderly residents at 8 nursing homes in France and Germany were enrolled between 2013 and 2015.

### Participants

The inclusion criteria were as follows: nursing home residents with oral or dental complaints (self-reported or reported by caregivers), willing to receive oral or dental preventive care, willing and able to provide written informed consent, and able to communicate well with the investigator and understand and comply with the requirements of the study. The exclusion criteria were as follows: a documented history of examinations conducted by a surgeon in the 12 months prior to signing the consent form, any surgical or medical condition resulting in confinement to a bed, and any preexisting health condition that would interfere with the ability to complete the study.

### Teledentistry Intervention

After receiving our request to conduct the consultations, participants were examined in a room dedicated to the provision of medical care. Details of the procedure were provided to all patients in advance. A dental assistant made video recordings of their oral cavities using a Tele Pack X endoscope (Karl Storz Endoskope, Tuttlingen, Germany) with a cold light source and integrated camera and digital video recorder. The rigid endoscope was equipped with a universal serial bus (USB) interface and secure digital (SD) card, and a 30° Hopkins rod lens system was used to record the oral cavity at an angle of 120°, thus including one or both dental arches. The SD card allowed the data of each patient to be coded separately; the initials of each subject were recorded, along with an F or A (for French and German patients, respectively).

The dental assistant transferred the video recordings from the SD card to an external disk for access by the dental surgeon no more than 1 day after the examination. Once on the surgeon's internal hard drive, the data were subjected to dual backup. The data were used within 15 days of the videos being recorded.

A dental surgeon used the videos to establish diagnoses. Specifically, the surgeon checked for dental pathologies and assessed chewing ability and the rehabilitation status of dental prostheses. The secondary outcomes were the presence of gingival inflammation or alveolar mucosa inflammation.

## In-Person Evaluation

Within a maximum of 7 days after the first examination, the patient was examined again in a conventional manner, that is, face-to-face, by the same dentist who made the first diagnosis. The Silness-Loe and Greene-Vermillion dental hygiene assessment indices were applied and a new diagnosis was established according to the same criteria used during the first examination. Then these diagnoses were compared to those established via the video recordings.

## Sample Size Calculation

The sample size was calculated according to clinical considerations. Based on 4% precision, 90% sensitivity, and 90% specificity [with 95% confidence intervals (CIs)], 214 subjects were required. We also allowed for a 10% dropout rate, and therefore recruited a total of 237 subjects.

## Data Analysis

Diagnoses were classified as true positives if they were made in both face-to-face and teledentistry examinations, as false negatives if made only in face-to-face examinations, and as false positives if made only via teledentistry. The following were calculated:

Sensitivity: number of true positives/(number of true positives + number of false negatives);

Specificity: true negatives/(false positives + true negatives);

Positive predictive value (PPV) of teledentistry: true positives/[true positives + false positives];

Negative predictive value (NPV): true negatives/(true negatives + false negatives).

Receiver operating characteristic (ROC) analyses were conducted to determine the diagnostic performance of teledentistry. All analyses were performed using SAS software (ver. 9.3; SAS Institute, Cary, NC). A 2-sided *P* value < .05 was taken to indicate statistical significance.

## Results

### Participants

In total, 237 participants were enrolled. Table 1 lists the socio-demographic and clinical characteristics of all included subjects. The mean age of the participants was 84.4 ± 8.3 years, and 139 (59.1%) were female. In total, 136 (69.4%) participants were classified as totally or partially dependent, 114 (48.5%) had hypertension, and 73 (31.0%) had neurodegenerative diseases. Furthermore, 142 (60.4%) participants had a maxillary dental prosthesis and 104 (44.3%) had mandibular dental prostheses. In all, 31 (13.2%) participants required assistance with eating and 84 (35.7%) experienced at least 1 kg weight loss during the previous 3 months. Two (0.8%) died during the study. Finally, 124 (53.4%) participants could not be examined in the dental surgery room because of their dependent status and were thus examined in their nursing home.

### Video Recordings

The median time to achieve patient installation was 2 minutes [interquartile range (IQR) = 4 minutes] and the video recordings were all 8 minutes in length (IQR = 4 minutes). The teledentistry examinations were conducted over 12 minutes (IQR = 6 minutes), and the face-to-face examinations took 20 minutes (IQR = 7 minutes). One patient (0.4%) was examined while in bed. In total, 194 (82.6%) patients were assisted by another person during the video recording, and 3 (1.3%) patients had salivary incontinence. In total, 224 (95.3%)

**Table 1**

Characteristics of Tel-e-dent Study Participants (N = 235)

Characteristic	
Age (y; mean ± SD)	84.4 ± 8.3
Women, n (%)	139 (59.1)
Dependence level, n (%)	
Totally dependent	16 (6.8)
Highly dependent	35 (14.9)
Partially dependent	112 (47.7)
Independent	72 (30.6)
BMI (mean ± SD)	26.5 ± 6.3
Current smoker, n (%)	4 (1.7)
Alcohol drinker, n (%)	19 (8.1)
Comorbidities, n (%)	
Chronic heart failure	98 (41.7)
Diabetes	52 (22.1)
Hypertension	114 (48.5)
Previous stroke	34 (14.5)
COPD	13 (5.5)
Neurodegenerative disease(s)	73 (31.0)
Psychiatric disorder(s)	66 (28.1)
Rheumatism	77 (32.8)
Hemopathy	27 (11.5)
Cancer	30 (12.8)
Denutrition or malnutrition	47 (20.0)
Bedsore	13 (5.5)
Treatments, n (%)	
Bisphosphonates	7 (3.0)
Antidepressants	57 (24.3)
Anxiolytics	56 (23.8)
Hypnotics	46 (19.6)
Neuroleptics	38 (16.2)
Antihypertensive	80 (34.0)
Anticoagulants and antiaggregants	110 (46.8)

BMI, body mass index; COPD, chronic obstructive pulmonary disease; SD, standard deviation.

patients (or their family members) rated the teledentistry system as acceptable. Table 2 lists the video recording quality parameters.

### Main Clinical Outcomes

#### Dental pathology: diagnostic accuracy

In total, 231 patients were assessed via both video recordings and in a face-to-face setting.

The sensitivity of teledentistry for diagnosing dental pathology was 93.8% (95% CI: 90.7%–96.9%) and the specificity was 94.2% (95% CI: 91.2%–97.2%; Table 3). The prevalence of dental pathology was 55.4%. The PPV was 95.2% (95% CI: 92.4%–98.0%), and the NPV was 92.4% (95% CI: 89%–95.8%; as Table 4). In ROC analyses, the area under the curve was 0.95 (95% CI: 0.92–0.98).

#### Secondary Clinical Outcomes

##### Chewing ability: assessment accuracy

The chewing abilities of 198 patients were evaluated. The sensitivity of teledentistry for assessing chewing ability was 85.0% (95% CI: 80.0%–90%), and the specificity was 82.8% (95% CI: 77.5–88.1; Table 3). The prevalence of dental functional units was 70.7%. The PPV was 92.2% (95% CI: 88.5%–95.9%), and the NPV was 69.6% (95% CI: 63.2%–76%; Table 4). Among the total sample, 421 (94.6%) dental functional units were revealed by teledentistry.

##### Rehabilitation of dental prostheses: assessment accuracy

There were 144 patients with dental prostheses. The sensitivity of teledentistry for assessing the rehabilitation status of dental prostheses was 87.8% (95% CI: 82.5%–93.1%) and the specificity was 90.3% (95% CI: 85.5%–95.1%; Table 3). The PPV was 78.3% (95% CI: 71.6%–

**Table 2**  
Technical Parameters of the Teledentistry Method Used in the Tel-e-dent Study (N = 235)

Quality of the Teledentistry Video Images	
Definition, n (%)	
Poor	17 (7.2)
Good	197 (83.8)
Excellent	21 (8.9)
Stability, n (%)	
Poor	17 (7.2)
Good	150 (63.8)
Excellent	68 (28.9)
Color, n (%)	
Poor	27 (11.5)
Good	150 (63.8)
Excellent	58 (24.7)
Framing, n (%)	
Poor	25 (10.6)
Good	163 (69.4)
Excellent	48 (20.4)
Coverage, n (%)	
Poor	51 (21.7)
Good	110 (46.8)
Excellent	74 (31.5)
Hard drive backups, n (%)	235 (100)

85%) and the NPV was 94.9% (95% CI: 91.3%–98.5%; Table 4). The prevalence of prosthetic rehabilitation was 28.5%.

## Discussion

### Main Findings

Teledentistry had excellent sensitivity (93.8%) and specificity (94.2%) for diagnosing dental pathologies among elderly nursing home residents (using face-to-face examination as a gold standard). The sensitivity (85.0%) of teledentistry was higher than the specificity (82.8%) for the assessment of chewing ability. Conversely, the specificity (90.3%) of teledentistry for assessing the rehabilitation status of dental prostheses was higher than the sensitivity (87.8%). Teledentistry was not associated with any serious adverse events, and the acceptability rate (95.3%) among residents and their families was excellent.

### Study Validity

Telemedicine for the management of chronic diseases, such as diabetes mellitus, holds substantial promise for overcoming barriers to care in various geographic and socioeconomic settings.<sup>9,10</sup> In rural areas, such barriers include geographic distance, poor weather, lack of public transportation, and a shortage of health care providers.<sup>11,12</sup> Older participants may be particularly affected by these factors, and thus may significantly benefit from telemedicine case management.<sup>13,14</sup>

**Table 3**  
Sensitivity and Specificity of the Teledentistry Method Used in the Tel-e-dent Study

Outcome	Evaluable, n (%)	Sensitivity (95% CI)	Specificity (95% CI)
Main outcome			
Dental pathology	231 (98.3)	93.8% (90.7%–96.9%)	94.2% (91.2%–97.2%)
Secondary outcomes			
Chewing ability	198 (84.3)	85.0% (80.0%–90.0%)	82.8% (77.5%–88.1%)
Dental prostheses rehabilitation success	144 (61.3)	87.8% (82.5%–93.1%)	90.3% (85.5%–95.1%)

**Table 4**  
Positive and Negative Predictive Values of the Teledentistry Method Used in the Tel-e-dent Study

Outcome	Evaluable, n (%)	PPV (95% CI)	NPV (95% CI)
Main outcome			
Dental pathology	231 (98.3)	95.2% (92.4%–98%)	92.4% (89.0%–95.8%)
Secondary outcomes			
Chewing ability	198 (84.3)	92.2% (88.5%–95.9%)	69.6% (63.2%–76.0%)
Dental prostheses rehabilitation success	144 (61.3)	78.3% (71.6%–85.0%)	94.9% (91.3%–98.5%)

Teledentistry, which could improve the quality of management, allows partial or complete management to be achieved remotely, even of patients located thousands of kilometers from health care centers or qualified dentists.<sup>8,15</sup> However, the teledentistry intervention that we evaluated in this study goes beyond merely cataloguing and tracking lesions, by allowing the assessment of the risk or probability that a lesion is malignant. Teledentistry interventions that do not assess lesion malignancy are of particular concern because patients may substitute such assessments for proper medical consultations. The teledentistry method used in this study was performed in nursing homes by dental assistants and a single caregiver. It is important to highlight that our procedure did not require physician involvement at any point, and yet the quality of the evaluations was high, as shown by the high rate (95.2%) of dental pathology diagnoses (ie, the primary outcome) classified as acceptable.

The increased number of telemedicine applications geared toward health-related decision-making has not gone unnoticed by the US Food and Drug Administration or French public health authorities. Nevertheless, telemedicine applications, including teledentistry, must be further evaluated to confirm their validity. A recent study suggested that optimized long-term oral care could be achieved via an integrated approach encompassing education, provision of resources, the employment of oral care “champions,” greater support from health care managers and administrators, and appropriate organizational policies.<sup>16</sup>

In our study, the diagnostic sensitivity and specificity of teledentistry was highest for dental pathologies. Our teledentistry method was quicker than face-to-face examinations (12 and 20 minutes, respectively), and standard, dental surgeon–led examinations were not superior, in terms of overall sensitivity, for diagnosing dental pathologies. For assessing gingival and alveolar mucosa inflammation, chewing ability, and the rehabilitation status of dental prostheses, the results of our teledentistry method approached those of classic methods. The video recordings used in our method were high definition, with excellent stability, color, framing, and coverage properties. In addition, with a fully optimized system, the visual parameters could be further improved by 5%–10%. The success rate of the hard drive backups was 100%.

### Limitations

This study had the limitation that not all patients could attend the dental clinic or department because of their dependent status.

### Strengths

All data were collected systematically via questionnaires and standardized, face-to-face assessments. Staff were trained in data-collection methods before the study to ensure high-quality data, and the sample size calculation was highly precise with respect to the main outcomes. In this way, the validity of our results was improved.



All patients were at high risk for dental pathologies, as evidenced by the physician and caregiver reports, and had at least 1 dental abnormality. This study was the first to evaluate the diagnostic accuracy of teledentistry, which could be widely used for preventing and detecting dental abnormalities among elderly nursing home residents. Our results highlight the fact that dental pathology is a major determinant of denutrition and accelerated cognitive decline in elderly people. A previous study highlighted the need for better dental care for residents of nursing home facilities.<sup>17</sup> Older adults with different diseases and conditions may die from different causes. The impact of terminal functional decline on oral health may differ among patients with different disease trajectories, and teledentistry may allow such patients to receive oral health care in a nursing home setting.<sup>18</sup> We documented teledentistry adherence rates of up to 99% among nursing home residents and their families. Studies of chronic heart failure patients have shown that patients can adapt quickly to teledentistry, view telephone-monitoring as an acceptable part of their health care routine, and are able to maintain good adherence for at least 12 months.<sup>19,20</sup>

## Conclusion

Teledentistry has excellent accuracy for diagnosing dental pathologies, and good accuracy for assessing the rehabilitation of dental prostheses and chewing ability among older adults living in nursing homes. The oral health status of the residents in our study was poor, regardless of medical diagnosis. A high level of unmet oral health needs, together with a strong desire among elderly patients to receive dental care, suggests that improving access to dental care for this growing population is imperative. In addition to improving awareness among geriatricians, dentists, and primary care providers, the medical community as a whole must collaborate with the dental care community to develop teledentistry programs tailored toward older adults, which may allow more regular checkups of frail and dependent people.

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