

Original Article

# Comparison of teledentistry and on-site clinical diagnosis using the International Caries Detection and Assessment System (ICDAS) in Rawalpindi and Islamabad: a validation study

Sufyan Ahmad <sup>a</sup>, Humaira Mahmood <sup>a</sup>, Muhammad Zubair Rafique <sup>a</sup>, Haseeb Ahmed <sup>b</sup>, Saqlain Bin Syed Gillani <sup>c</sup>, Qurat Ul Ain <sup>c</sup>, Manahil Rahat <sup>a</sup>, Hassan Mumtaz <sup>d,\*</sup>

<sup>a</sup> Armed Forces Postgraduate Medical Institute, Rawalpindi, Pakistan

<sup>b</sup> Rawal Institute of Health Sciences, Islamabad, Pakistan

<sup>c</sup> Islamic International Dental College, Islamabad, Pakistan

<sup>d</sup> BPP University, London, United Kingdom

\* Correspondence: hassanmumtaz.dr@gmail.com; Telephone: +447506326264



**Citation:** Ahmad S, Mahmood H, Rafique MZ, Ahmed H, Gillani SBS, Ain QU, et al. Comparison of teledentistry and on-site clinical diagnosis using the International Caries Detection and Assessment System (ICDAS) in Rawalpindi and Islamabad: a validation study. J Basic Clin Med Sci. 2023;2:23-29.

**Received:** 18 August 2023

**Revised:** 23 September 2023

**Accepted:** 27 September 2023

**Published:** 04 October 2023

**Publisher's Note:** Logixs Journals remains neutral concerning jurisdictional claims in its published subject matter, including maps and institutional affiliations.



**Copyright:** © 2023 The Author(s).

This is an open access article distributed under the terms of the [Creative Commons Attribution \(CC BY\) License](https://creativecommons.org/licenses/by/4.0/). The use, distribution, or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is

## Abstract

Dental caries significantly impact global health, particularly in Pakistan, where the prevalence is notably high. This study assessed the diagnostic accuracy of mobile teledentistry in Islamabad and Rawalpindi by employing the International Caries Detection and Assessment System (ICDAS) as a benchmark. This cross-sectional validation study was conducted from July to September 2022 in nine private dental clinics involving 460 participants proficient in basic Android smartphone functions. The diagnostic procedure comprised initial in-person evaluations by dentists, subsequent remote assessments using images captured by smartphones based on verbal instructions, and validations by a third independent dentist. Statistical analyses were performed using sensitivity, specificity, Matthew's correlation coefficient, and receiver operating characteristic (ROC) curves. Teledentistry achieved a specificity of 89% and a sensitivity of 70%. The positive and negative predictive values were 74.6% and 86%, respectively. The ROC curve analysis, with an area under the curve greater than 0.7, confirmed the high diagnostic efficacy of the method. The Cohen's kappa statistic reached 0.814, demonstrating substantial interrater reliability, while the diagnostic odds ratio was 18, indicating strong discriminative power. This study confirmed that teledentistry, enabled by the use of smartphone cameras, serves as a reliable method for detecting dental caries, with efficacy comparable to that of conventional clinical examination methods. It significantly extends dental care accessibility, particularly in geographically remote or economically underserved regions, effectively mitigating the logistical challenges associated with traditional dental visits. The findings support the broader implementation of teledentistry, highlighting its potential to enhance mass screening efforts, improve oral health outcomes, and alleviate pressures on healthcare systems across diverse demographic landscapes.

## Keywords

Teledentistry; Telecommunications; Delivery of healthcare; Dental software; Dental caries

## 1. Introduction

Since the dawn of humanity, the need for dental treatment has become evident as oral diseases continue to pose a significant global health challenge [1]. It is evident from historical analyses that dental caries, a predominant oral condition, has afflicted humans since antiquity, as evidenced by carious teeth found in ancient skeletal remains [2,3]. According to the Global Burden of Disease Study 2017, oral diseases are considered among the most prevalent noncommunicable diseases worldwide, affecting approximately 3.5

permitted which does not comply with these terms.

billion people. Among these, approximately 2.3 billion people suffer from untreated caries in their permanent teeth, while approximately 532 million children experience untreated caries in their deciduous (baby) teeth [4,5,6].

Oral health is an important indicator of overall health and well-being. However, in many regions, it is regarded more as a personal responsibility than a collective societal concern [5]. Inadequate oral hygiene not only impacts eating and speaking abilities but is also associated with critical noncommunicable diseases such as respiratory disorders, cancers, and cardiovascular conditions [5,7,8]. The worldwide impact of oral diseases is considerable, with approximately 15 million disability-adjusted life years reported as lost in 2017, alongside notable economic burdens costing approximately 298 billion dollars in treatment expenses and 144 billion dollars due to productivity losses [9].

In Pakistan, the burden of dental caries is particularly high, with national studies indicating a prevalence of approximately 56.62%, reflecting significant regional variations [10]. Moreover, in Bhara Kahu, Islamabad—where this study is based—the prevalence among preschool children has been reported to be 49% [11]. This high incidence underscores the urgent public health challenge posed by oral diseases in the country and highlights the critical need for innovative solutions to improve oral healthcare delivery [12].

The introduction of teledentistry has emerged as a significant innovation in dental care, especially during the COVID-19 pandemic, when traditional in-person consultations were frequently disrupted, demonstrating its potential to maintain continuity of care [13,14,15]. However, despite its promise, the body of research on teledentistry is still limited, with a particular lack of rigorous, comparative studies that examine its efficacy on an individual basis [13]. Additionally, there is a notable gap in the literature regarding the reliability of teledentistry outcomes when services are rendered by varying dentists rather than a consistent practitioner [16].

This study aimed to evaluate the effectiveness of mobile teledentistry in Islamabad and Rawalpindi, specifically focusing on its specificity, sensitivity, and predictive value when utilized by individuals without specialized photographic skills. The objective of this study was to determine the diagnostic accuracy of mobile teledentistry using the International Caries Detection and Assessment System (ICDAS) as a reference, assessing its potential to deliver accurate diagnoses in a nonclinical setting.

## 2. Methods

This cross-sectional validation study was conducted from July to September 2022 across nine private dental clinics in Rawalpindi and Islamabad, which were selected for their comprehensive facilities necessary to support the research. Ethical approval was obtained from the Ethical Review Committee of the Armed Forces Post Graduate Medical Institute (AFPGMI), Rawalpindi (No. 249-AAA-ERC-AFPGMI).

To enhance the study's power, the sample size was increased from 156 to 480, based on initial calculations from the Raosoft sample size calculator targeting a sensitivity of 88.5%, a margin of error of 5%, and a 95% confidence interval, referencing findings from a recent 2022 study [17,18]. The study employed a nonprobability consecutive sampling technique.

The participants included were individuals of both genders who had basic knowledge of Android smartphone camera functions. The study excluded individuals who were unwilling to provide consent or who did not meet specific health criteria necessary for accurate dental assessments, such as those with preexisting conditions that could interfere with dental evaluations. Written informed consent was obtained from all participants prior to data collection.

The data were collected using a structured questionnaire focused on dental health and the applicability of teledentistry. The diagnostic process comprised three phases: an initial in-person evaluation of dental caries by a dentist using ICDAS [19], followed by a remote assessment by another dentist using images taken based on verbal instructions, and a validation of these diagnoses by a third independent dentist.



**Figure 1.** A demonstration of an ideal set of pictures for the diagnosis of dental caries for android users.

Data analysis was conducted using SPSS version 21.00, and the results are presented as frequencies and percentages. The study computed measures such as sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of the photographic diagnosis method. The effectiveness of this method was evaluated using a receiver operating characteristic (ROC) curve by plotting sensitivity against specificity. Interrater reliability was assessed using Cohen's kappa statistic, and Youden's index was calculated.

### 3. Results

A total of 460 patients were examined. The specificity of teledentistry in reference to clinical check scoring of the ICDAS was 89%. The sensitivity was 70%, whereas the

negative predictive value and positive predictive value were 86% and 74.6%, respectively (Table 1).

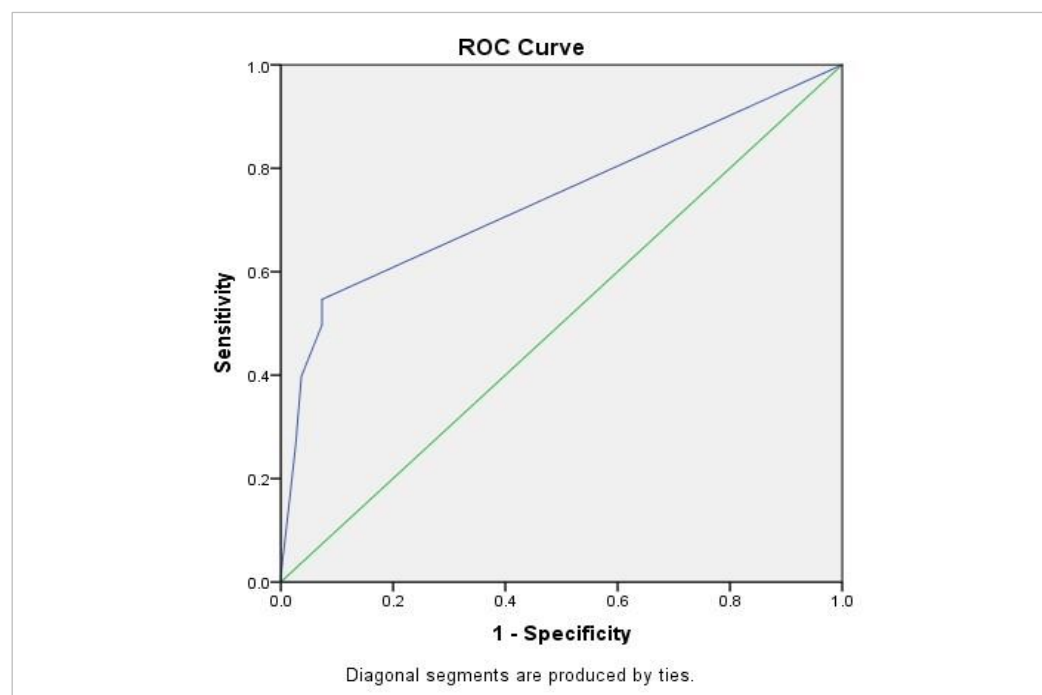
**Table 1.** Performance of teledentistry and physical examination in dental caries detection using ICDAS.

Description		Physical Examination		Total
		Caries Positive	Caries Negative	
Teledentistry	Caries Positive	103 True Positive (TP)	35 False Positive (FP)	138
	Caries Negative	46 False Negative (FN)	286 True Negative (TN)	332
Total		149	321	460

The evaluation of teledentistry's diagnostic accuracy revealed a sensitivity of 69.79%, indicating its ability to correctly identify the presence of dental caries in patients. The specificity was determined to be 89%, demonstrating its effectiveness in correctly ruling out patients without the disease. Moreover, the Youden's index, a measure of the overall effectiveness of the diagnostic test, was calculated at 58.79.

Further in-depth analysis revealed that the MCC was 0.595, reflecting a moderate quality of the diagnostic process. The Cohen's kappa coefficient reached 0.814, indicating substantial interrater agreement and consistency across different evaluators. The diagnostic odds ratio was 18, indicating the strong discriminative power of the test. Moreover, the Balanced Accuracy of the test was 73.40%, showing its accuracy in identifying both conditions—diseased and nondiseased.

The area under the ROC curve for teledentistry was greater than 0.7, highlighting its ability to discriminate between patients with and without dental caries, thus confirming its strong diagnostic accuracy.



**Figure 1.** ROC curve illustrating the sensitivity and specificity of teledentistry with an area under the ROC curve of 0.7.

#### 4. Discussion

Teledentistry has been a valuable tool in Pakistan for a long time, and its effectiveness during the COVID-19 pandemic has been demonstrated [20,21,22]. Despite its extensive use, comprehensive validity research within Pakistan remains scarce. A systematic review revealed wide variability in the reported validity of teledentistry, with a sensitivity ranging from 25–100% and a specificity ranging from 68–100%, indicating diverse diagnostic accuracies across different settings [23].

Studies in other regions also reflect this variability. For instance, a study in rural India reported high sensitivity using video-based teledentistry [24], while a randomized controlled trial noted similarly high sensitivity [25]. High sensitivity was also observed in studies employing ICDAS for diagnosis, particularly in controlled, in vitro settings using high-quality cameras [26,27]. Conversely, studies that utilized less specialized photographic methods generally reported lower sensitivity, similar to findings in our context where photography was conducted by patients' attendants based on verbal instructions.

A study conducted by Kopycka-Kedzierawski suggested that intraoral cameras could be a cost-effective alternative to traditional visual examinations, especially for underserved populations, reinforcing the potential of teledentistry as a scalable solution for broad application [28]. Other studies have shown teledentistry to be reliable, supporting its continued use and development [29,30,31].

This study benefits from a real-world application in urban centers, integrating the latest mobile technology, which makes it highly relevant to today's digital health landscape. The use of the ICDAS provides a standardized diagnostic criterion, enhancing the study's reliability. However, the study is limited by its focus on urban populations, potentially limiting the applicability of the results to rural or less technologically equipped areas. The variability in image quality, which is dependent on nonspecialist photography, could also impact diagnostic accuracy. Additionally, while the study provides insights into the feasibility of teledentistry, geographic and technological constraints may affect the generalizability of the findings.

#### 5. Conclusions

This study confirmed that teledentistry, facilitated by the use of smartphone cameras, serves as a reliable method for detecting dental caries with efficacy comparable to that of conventional clinical examination methods. Moreover, the delegation of nondentist personnel for image acquisition significantly extends dental care accessibility, particularly in geographically remote or economically underserved regions. The use of smartphones in this diagnostic context effectively mitigates the logistical challenges associated with traditional dental visits. It reduces both physical and psychological discomfort for patients. The findings advocate for the expanded implementation of teledentistry, underscoring its potential to enhance mass screening efforts, improve oral health outcomes, and alleviate pressures on healthcare systems across diverse demographic landscapes.

**Author contributions:** Conceptualization, SA, HM, MZR, and HA; methodology, SA, HM, MZR, HA, QUA, MR, and HM; software, SBSG, QUA, and HM; validation, HA; formal analysis, SBSG, QUA, and HM; investigation, SA, HM, MZR, and MR; resources, HA; data curation, SBSG, QUA, and HM; writing—original draft preparation, SA, HM, MZR, SBSG, QUA, MR, and HM; writing—review and editing, HA; visualization, MZR, SBSG, QUA, and HM; supervision, HA; project administration, HA. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no specific grant from public, commercial, or not-for-profit funding agencies.

**Ethics statement:** Ethical approval was obtained from the Ethical Review Committee of the Armed Forces Post Graduate Medical Institute (AFPGMI), Rawalpindi (No. 249-AAA-ERC-AFPGMI).

**Consent to participate:** Written informed consent was obtained from all participants prior to data collection.

**Data availability:** The data supporting this study's findings are available from the corresponding author, Hassan, upon reasonable request.

**Acknowledgments:** None.

**Conflicts of interest:** The authors declare no conflicts of interest.

## References

- [1] Peres MA, Macpherson LM, Weyant RJ, Daly B, Venturelli R, Mathur MR, et al. Oral diseases: a global public health challenge. *Lancet*. 2019;394(10194):249-60. [https://doi.org/10.1016/S0140-6736\(19\)31146-8](https://doi.org/10.1016/S0140-6736(19)31146-8)
- [2] Massingham S. Uncovering the tooth: interventional dental therapy in Ancient Egypt [dissertation]. Sydney (AU): Macquarie University; 2021.
- [3] Bertilsson C, Borg E, Sten S, Hessman E, Sjöblom H, Lingström P. Prevalence of dental caries in past European populations: a systematic review. *Caries Res*. 2022;56(1):15-28. <https://doi.org/10.1159/000522326>
- [4] Rigo L, Bidinotto AB, Hugo FN, Neves M, Hilgert JB. Untreated caries and serum vitamin D levels in children and youth of the United States: NHANES 2013-2014. *Braz Dent J*. 2023;34(1):99-106. <https://doi.org/10.1590/0103-6440202305123>
- [5] World Health Organization. Oral Health. 2023 [cited 27 July 2023]. Available from: <https://www.who.int/news-room/fact-sheets/detail/oral-health>.
- [6] GBD 2017 Oral Disorders Collaborators, Bernabe E, Marcenes W, Hernandez CR, Bailey J, Abreu LG, et al. Global, regional, and national levels and trends in burden of oral conditions from 1990 to 2017: a systematic analysis for the global burden of disease 2017 study. *J Dent Res*. 2020;99(4):362-73. <https://doi.org/10.1177/0022034520908533>
- [7] Almutlaqah MA, Baseer MA, Ingle NA, Assery MK, Al Khadhari MA. Factors affecting access to oral health care among adults in Abha City, Saudi Arabia. *J Int Soc Prev Community Dent*. 2018;8(5):431-38. [https://doi.org/10.4103/jispcd.jispcd\\_205\\_18](https://doi.org/10.4103/jispcd.jispcd_205_18)
- [8] Kane SF. The effects of oral health on systemic health. *Gen Dent*. 2017;65(6):30-4.
- [9] Listl S, Grytten JI, Birch S. What is health economics?. *Community Dent Health*. 2019;36(4):263-75. [https://doi.org/10.1922/cdh\\_4581listl13](https://doi.org/10.1922/cdh_4581listl13)
- [10] Siddiqui AA, Alshammary F, Mulla M, Al-Zubaidi SM, Afroze E, Amin J, et al. Prevalence of dental caries in Pakistan: a systematic review and meta-analysis. *BMC Oral Health*. 2021;21(1):450. <https://doi.org/10.1186/s12903-021-01802-x>
- [11] Masoud S, Qazi SH, Mumtaz R. Prevalence of dental caries and its association with risk factors amongst preschool children of Bhakrah, Islamabad. *J Islamabad Med Dent Coll*. 2020;9(2):88-94. <https://doi.org/10.35787/jimdc.v9i2.463>
- [12] Basharat S, Shaikh BT. Primary oral health care: a missing link in public health in Pakistan. *East Mediterr Health J*. 2016;22(9):703-6. <https://doi.org/10.26719/2016.22.9.703>
- [13] Giudice A, Barone S, Muraca D, Averta F, Diodati F, Antonelli A, et al. Can teledentistry improve the monitoring of patients during the Covid-19 dissemination? a descriptive pilot study. *Int J Environ Res Public Health*. 2020;17(10):3399. <https://doi.org/10.3390/ijerph17103399>
- [14] Cheuk R, Adeniyi A, Farmer J, Singhal S, Jessani A. Teledentistry use during the COVID-19 pandemic: perceptions and practices of Ontario dentists. *BMC Oral Health*. 2023;23:72. <https://doi.org/10.1186/s12903-023-02772-y>
- [15] Garfan S, Alamoodi AH, Zaidan BB, Al-Zobbi M, Hamid RA, Alwan JK, et al. Telehealth utilization during the Covid-19 pandemic: a systematic review. *Comput Biol Med*. 2021;138:104878. <https://doi.org/10.1016/j.compbiomed.2021.104878>
- [16] AlShaya MS, Assery MK, Pani SC. Reliability of mobile phone teledentistry in dental diagnosis and treatment planning in mixed dentition. *J Telemed Telecare*. 2020;26(1-2):45-52. <https://doi.org/10.1177/1357633X18793767>
- [17] AlShaya M, Farsi D, Farsi N, Farsi N. The accuracy of teledentistry in caries detection in children—a diagnostic study. *Digit Health*. 2022;8:1-4. <https://doi.org/10.1177/20552076221109075>
- [18] Zaidi SMH, Waseem HF, Ansari FA, Irfan M, Fahim S. Sample size estimation of diagnostic test studies in health sciences. *Proceedings of 14th International Conference on Statistical Sciences*; 2016 Mar 14; Karachi, Pakistan. p. 239-46.
- [19] Ismail AI, Sohn W, Tellez M, Amaya A, Sen A, Hasson H, et al. The International Caries Detection and Assessment System (ICDAS): an integrated system for measuring dental caries. *Community Dent Oral Epidemiol*. 2007;35(3):170-8. <https://doi.org/10.1111/j.1600-0528.2007.00347.x>
- [20] Mian FH. Teledentistry in dental healthcare of Pakistan. *J Pak Dent Assoc*. 2015;24(4):172-4.
- [21] Plaza-Ruiz SP, Barbosa-Liz DM, Agudelo-Suárez AA. Impact of COVID-19 on the knowledge and attitudes of dentists toward teledentistry. *JDR Clin Trans Res*. 2021;6(3):268-78. <https://doi.org/10.1177/2380084421998632>
- [22] Subhan R, Ismail WA, Musharraf S, Khan M, Hafeez R, Alam MK. Teledentistry as a supportive tool for dentists in Pakistan. *Biomed Res Int*. 2021;2021:8757859. <https://doi.org/10.1155/2021/8757859>
- [23] Alabdullah JH, Daniel SJ. A systematic review on the validity of teledentistry. *Telemed J E Health*. 2018;24(8):639-48. <https://doi.org/10.1089/tmj.2017.0132>

- [24] Purohit BM, Singh A, Dwivedi A. Utilization of teledentistry as a tool to screen for dental caries among 12-year-old school children in a rural region of India. *J Public Health Dent.* 2017;77(2):174-80. <https://doi.org/10.1111/jphd.12195>
- [25] Palaskar JN. Randomized control trial: an overview. *J Dent Allied Sci.* 2016;5:1-2. <https://doi.org/10.4103/2277-4696.185186>
- [26] Gomez J, Zakian C, Salsone S, Pinto SC, Taylor A, Pretty IA, et al. In vitro performance of different methods in detecting occlusal caries lesions. *J Dent.* 2013;41(2):180-6. <https://doi.org/10.1016/j.jdent.2012.11.003>
- [27] Kohara EK, Abdala CG, Novaes TF, Braga MM, Haddad AE, Mendes FM. Is it feasible to use smartphone images to perform telediagnosis of different stages of occlusal caries lesions? *PLoS One.* 2018;13(9):e0202116. <https://doi.org/10.1371/journal.pone.0202116>
- [28] Kopycka-Kedzierawski DT, Billings RJ, McConnochie KM. Dental screening of preschool children using teledentistry: a feasibility study. *Pediatr Dent.* 2007;29(3):209-13.
- [29] Morosini IAC, Canavese de Oliveira D, Fernanda FM, Fraiz FC, Torres-Pereira CC. Performance of distant diagnosis of dental caries by teledentistry in juvenile offenders. *Telemed J E Health.* 2014;20(6):584-9. <https://doi.org/10.1089/tmj.2013.0202>
- [30] Boye U, Willasey A, Walsh T, Tickle M, Pretty IA. Comparison of an intra-oral photographic caries assessment with an established visual caries assessment method for use in dental epidemiological studies of children. *Community Dent Oral Epidemiol.* 2013;41(6):526-33. <https://doi.org/10.1111/cdoe.12049>
- [31] Mantas J, Adlassnig KP, Mantas J, editors. Medical informatics in a united and healthy Europe. Proceedings of MIE; 2009 Aug 30 - Sep 2; Sarajevo, BA. Amsterdam: IOS Press; 2009.