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Bridging the Gap: Digital Innovation and Interoperability in Healthcare and Dentistry

[1]Dr. Sai Vyshnavi.CH, Randolph Dental Care, North Carolina, USA.

[2]Dr. Sowmya Pasupuleti, Randolph Dental Care, North Carolina, USA.

Corresponding Author: Dr. Sai Vyshnavi.CH, Randolph Dental Care, North Carolina, USA.

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Abstract

Dentistry is undergoing a transformative shift through the integration of digital technologies, redefining oral healthcare delivery and accessibility. Innovations such as tele dentistry, artificial intelligence (AI), digital imaging, and electronic health records (EHRs) are addressing disparities, enhancing preventive care, and improving patient engagement.

Tele dentistry facilitates remote consultations, extending access to underserved populations, while AI-driven tools enable early detection and personalized treatment planning. The integration of data analytics and digital platforms optimizes resource allocation and streamlines oral health programs. This paper explores the transformative potential of digital innovations in reshaping public oral healthcare systems, emphasizing opportunities and challenges in building a more inclusive and efficient framework.

While digital technologies provide significant benefits, including improved accuracy, efficiency, and patient outcomes, considerations such as cost, training, and data security must be addressed. With ongoing advancements, the future of dentistry promises further innovations and enhanced patient care, paving the way for a more accessible and equitable oral health landscape.

Keywords: APIs (Application Programming Interfaces) Interoperability DCIOM (Digital Imaging and Communications in Medicine) EHR (Electronic Health Records) FHIR (Fast Healthcare Inoperability resources)

Introduction

In recent times, data has become a cornerstone of exchange across various sectors. Concepts such as "big data," "machine learning," "deep learning," and "artificial intelligence" have converged to create powerful tools for data analysis. These technologies are being employed in diverse fields, including astronomy, retail, automotive industries, web search engines, and even politics (Murdoch and Detsky, 2013).

In the healthcare sector, the potential for big data is immense, with estimates predicting the generation of zettabytes and yottabytes of data (Glick, 2015). To leverage such vast amounts of information, data must first be organized and structured to ensure it is accessible, analyzable, and reusable (Obermeyer and Emanuel, 2016). This requires data to be formatted in a way that is understandable to both humans and computers.

However, a significant challenge lies in the fragmentation of healthcare data, often hidden in isolated silos and incompatible systems, which limits its usability (Lehne et al., 2019). To overcome these barriers and

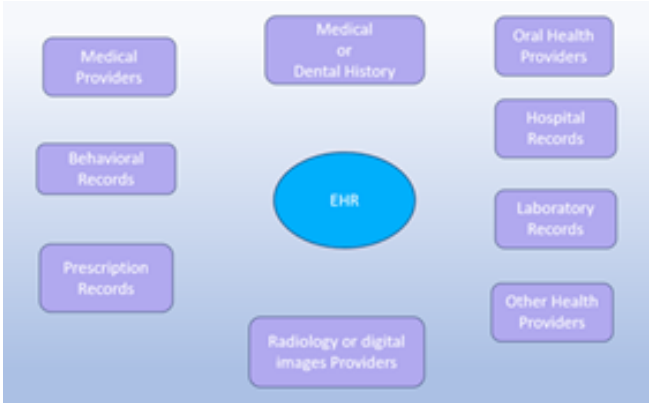
enhance healthcare quality, accessibility, safety, affordability, and equity, both medical and dental sectors are increasingly adopting advanced information technologies.

Electronic Health Records (EHR) in Dentistry

The adoption of Electronic Health Records (EHR) has been transformative in healthcare but presents challenges such as text-free data entry, which can lead to inconsistencies and reduce data usability. Dentistry, in particular, has lagged behind in adopting information technology systems, making the implementation of electronic dental records (EDRs) a critical starting point. EDRs enable the efficient recording, storage, and exchange of healthcare standards (Joda et al., 2019).

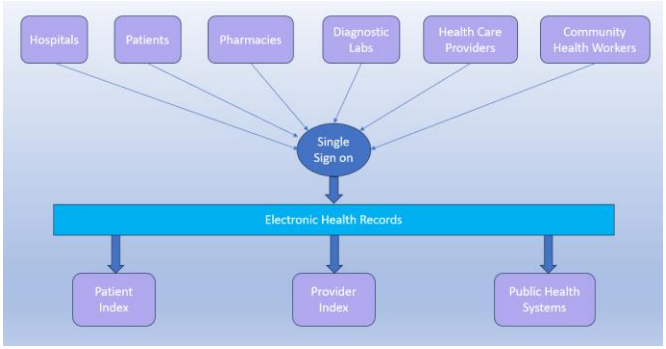
In the United States, the push toward interoperability-enabled EHR systems has advanced significantly, promoting seamless information exchange. Meanwhile, Europe follows the FAIR principles (Findable, Accessible, Interoperable, Reusable) through initiatives like the European Open Science Cloud, which provides resources to support these standards.

The field of dental informatics is rapidly growing, with many dental schools integrating EHRs and other digital systems into their curricula. A Harvard University exploratory study surveyed physicians and dentists across four academic medical centers to evaluate EHR usage. Among 118 respondents, 63.9% were dentists, and 66.3% rated EHRs highly (8 on a 10-point Likert scale), with dentists scoring higher than physicians. Furthermore, 68.5% of providers believed that EHR usage could significantly enhance patient care. Both groups emphasized the importance of oral-systemic health and agreed that interoperable EHRs could facilitate information transfer and advance research on oral-systemic connections.



In the United States, EHR adoption has become widespread, with 86% of physicians using EHRs and 80% maintaining certified systems by 2017, as reported by the Office of the National Coordinator for Health Information Technology. Germany has also made significant strides, introducing a personal electronic health card in 2004, followed by an E-Health law in 2015 that incentivized EHR adoption.

A separate survey conducted across Germany, Harvard School of Dental Medicine, the University of Pittsburgh (Pitt), and the University of California, San Francisco (UCSF) highlighted EHR adoption trends. Among the 508 respondents, the response rate was 23.2%, with the majority of dentists specializing in prosthodontics (63.9%). Dentists showed greater interest in EHR utilization than physicians, with the highest response rate observed at UCSF. These findings underscore the growing enthusiasm among dental professionals for incorporating EHRs to enhance healthcare delivery and research.



Limitations of EHR

1. Inability to Communicate the Information Process EHR systems often struggle to facilitate seamless communication of information, leading to inefficiencies in data sharing and processing.
2. Inconsistencies in Data Errors in data collection can result in significant inconsistencies. For example, the DMF index recorded in Finland showed considerable variation due to data inaccuracies. Similarly, in cases involving dental caries in children and Apgar scores, missing variables for certain individuals created obstacles during statistical analysis, complicating the interpretation and reliability of the data (Song et al., 2013).

Medical and Dental EHR Integration and Its Impact on Diabetes Care

Oral health is often overlooked in primary care settings during general health checkups, leading to missed diagnoses and treatment opportunities. Marshfield Clinic Health System (MCHS), established in 1916, is one of the largest integrated health systems in the United States. By integrating medical and dental EHRs, MCHS improved diabetes care and outcomes.

Data from 2018-2019 revealed that 18% of MCHS medical and dental patients were diagnosed with diabetes. However, 7% of these patients visited only medical settings, neglecting dental care. To address this, the Clinical Decision Support Alert Tool (CDSAT) was introduced to identify and manage diabetes cases. CDSAT triggered alerts in the EHRs of 7,723 patients, prompting action.

As a result, primary care physicians conducted oral health examinations for 64% of the diabetic patients, referred 170 patients to dentists, and advised 626 to seek dental care. These tools also demonstrated potential in predicting diabetes and its associated risks, particularly in rural areas of Wisconsin and Michigan. This facilitated timely prevention and management interventions, highlighting the value of integrated medical and dental EHR systems in improving overall health outcomes.

What is Interoperability?

Interoperability refers to the ability of different systems to exchange and utilize data seamlessly (Geraci, 1991). It is also defined as the health information technology that enables secure exchange of electronic health information without requiring special effort from users. This allows complete access, exchange, and use of all electronically accessible health information, as governed by applicable state or federal laws (Section 4003 of the 21st Century Cures Act).

Types of Interoperability

1. **Technical Interoperability**

This forms the foundation for information exchange, enabling data to move from one system (System A) to another (System B) regardless of distance or domain. Effective healthcare data exchange requires a combination of technical, semantic, and syntactic interoperability.

2. **Syntactic Interoperability**

This focuses on the format and structure of data. Standards such as FHIR (Fast Healthcare Interoperability Resources) are widely adopted for healthcare data communication.

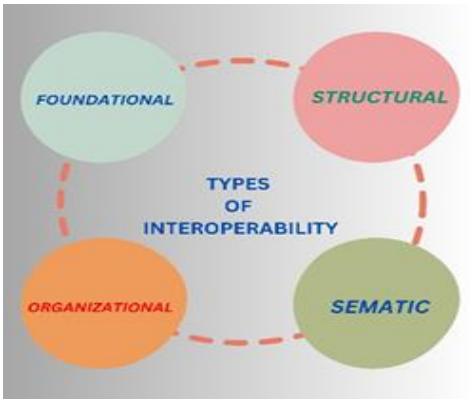
3. **Semantic Interoperability**

This type addresses the meaning of data, ensuring accurate interpretation by humans and computers. It involves medical terminologies and standards such as FHIR, open EHR, and SNOMED CT (Systematized Nomenclature of Medicine—Clinical Terms), which includes around 340,000 concepts. Other examples include Identifiers of Medicinal Products (for medicine),

the HUGO Gene Nomenclature Committee (for genes), and the Human Phenotype Ontology (for phenotypic ontologies).

4. **Organizational Interoperability**

Considered the highest level of interoperability, this type focuses on organizational processes, legislations, and policies to ensure seamless collaboration between institutions.



Factors Impacting Interoperability

1. **Data Gathering**

Effective data collection remains a significant challenge for interoperability. Issues like information blocking have been highlighted by researchers, including Julia Adler-Milstein, PhD, and Eric Pfeifer, with approximately 50% of respondents acknowledging its presence. Addressing this issue could significantly enhance the quality and efficiency of healthcare delivery.

2. **Standard Protocols**

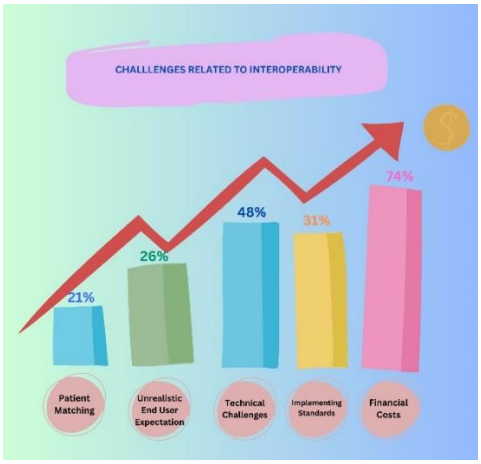
Implementing standard protocols for communication among all stakeholders can enhance interoperability. Infrastructure improvements and adherence to common policies for APIs (Application Programming Interfaces) and standards like FHIR (Fast Healthcare Interoperability Resources) play a vital role in streamlining processes.

3. **Technical Challenges**

Complexities in integrating and maintaining different systems pose significant hurdles for achieving seamless data exchange.

4. **Economic and Financial Disincentives**

The costs associated with implementing and maintaining interoperable systems can deter adoption, particularly for smaller organizations.



Benefits of Interoperability

1. **Cost Efficiency Through HER**

Current EHR systems often operate in silos, resulting in inefficiencies such as manual data entry and transfer, which waste an estimated $36 billion in time. Interoperable systems reduce these inefficiencies and offer significant financial benefits to users.

2. **Simplified Data Exchange**

Interoperable EHR systems alleviate clinicians' concerns about excessive time spent on data entry. They enable seamless data sharing, which supports research into rare diseases, precision medicine, and drug development. Frameworks like Integrating the Healthcare Enterprise (IHE) ensure secure data transfer while meeting international standards.

3. **Advancing Dental Research**

Innovations like digital radiographs, CAD/CAM, 3D printing, and milling generate large volumes of data that can enhance dental research. Emerging technologies, such as IoT-enabled devices like saliva-analyzing mouthguards and smart toothbrushes, provide valuable

real-world data to address epidemiological and public health challenges.

4. **Error Reduction and Efficiency Gains**

Interoperable systems reduce errors and enhance the efficiency of healthcare delivery processes.

5. **Accurate Reporting**

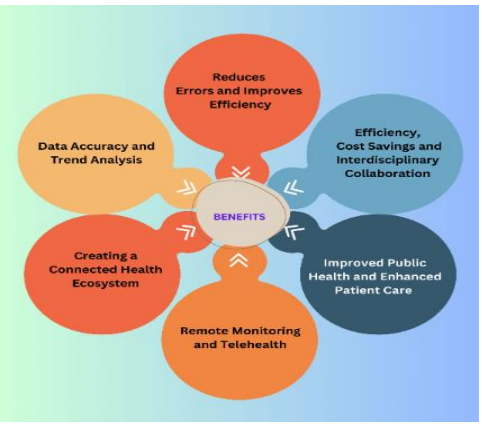
Improved data accuracy ensures reliable reporting, aiding in better decision-making and care quality.

6. **Enhanced Patient Records Access**

Interoperability facilitates streamlined access to comprehensive patient records, improving continuity of care.

7. **Improved Patient Safety**

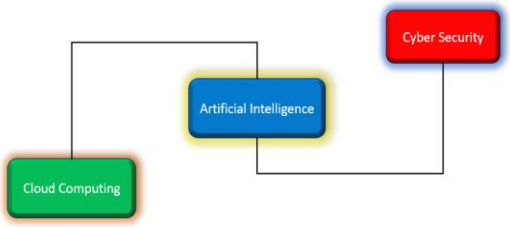
Enhanced data sharing reduces risks, promotes timely interventions, and ensures safer patient outcomes.



Digital Transformation in Dentistry

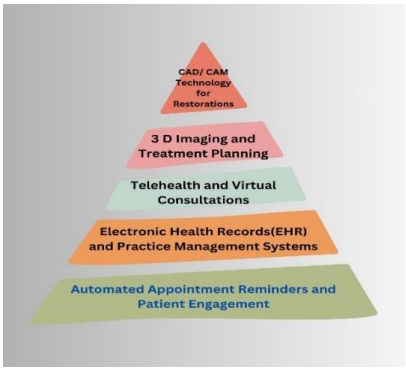
The rapid evolution of digital technology has profoundly impacted dentistry, revolutionizing dental education, clinical practices, business management, and communication. These advancements have enabled early diagnosis, enhanced treatment outcomes, and improved patient care. Digital transformation in dentistry spans four key dimensions: patient-centric platforms, evolving IT and digital skills, data governance, and the adoption of technology within dental settings. By focusing on patient experience, embracing innovative IT solutions, ensuring robust data management, and integrating technology into daily practice, dentistry has entered a new era of efficiency and precision.

Mobile applications have become a powerful tool for oral health promotion and education, offering interactive and engaging content to empower patients. Apps like the Feno App, along with AI-powered Feno toothbrushes, analyze oral health issues and provide users with valuable insights into their oral cavity, aiding in diagnosis and treatment planning. Similarly, platforms like “mHealth” enhance patient education about oral diseases and improve adherence to treatment protocols. Specialized applications such as the “Paro-Com Pas” app support individuals with periodontitis by guiding them through their treatment journey, thereby improving their quality of life. Digital companions like “mySugar” offer continuous therapy support, encouraging better compliance with treatment plans. Additionally, smart tools like AI-enabled toothbrushes and telematics-integrated platforms promote self-care practices and foster greater patient engagement. Furthermore, robotic systems powered by artificial intelligence are transforming dentistry by improving precision in procedures such as implant placements and root canal treatments. Automation of repetitive tasks like polishing, when assisted by robots, reduces human fatigue, enhancing efficiency and outcomes in dental care.



Measurement of digital adoption is critical in dentistry, with tools like the Dental Data Synthetic Index (DDSI) providing insights into digital progress within organizations. Standards like DICOM are increasingly implemented to enable the electronic sharing of diagnostic images such as radiographs. The rise of technologies like artificial intelligence, machine learning, and block chain provides new possibilities for improved diagnostics, personalized care, and patient-centered services in dentistry.

Artificial intelligence (AI) and machine learning (ML) have the potential to revolutionize disease surveillance and public health interventions by leveraging large datasets from diverse sources such as electronic health records (EHRs), social media platforms, and demographic data. In public health dentistry, these technologies can enable the implementation of targeted preventive measures, optimize resource allocation, and aid in designing effective oral health programs. By identifying trends and patterns in data, AI and ML can support proactive decision-making, enhancing the overall impact of public health initiatives and improving oral health outcomes at the community level.



Future Perspectives

Digital transformation is revolutionizing oral healthcare by enhancing patient engagement, streamlining practice management, and improving health outcomes. Artificial intelligence (AI) holds immense promise in dentistry, offering transformative capabilities in diagnosis, treatment planning, and patient care. A key advancement is personalized dentistry, where AI analyzes patient data, including genomics and microbiomes, to create tailored hygiene routines and dietary recommendations, fostering better oral health. AI-powered systems can also monitor behaviors like teeth grinding or poor brushing techniques, providing real-time feedback to encourage healthier habits. Emerging technologies like Virtual Reality (VR) and Augmented Reality (AR), when integrated with AI, are creating groundbreaking opportunities in training and clinical applications. VR enables dental professionals to practice procedures such as cavity fillings, root canals, and implant placements in risk-free virtual environments, while AR overlays 3D anatomical projections to enhance understanding of complex structures. AI-enhanced VR systems evaluate trainee performance by analyzing precision, speed, and technique, ensuring effective skill development. Additionally, VR-based distraction therapy can reduce patient anxiety during treatments, and AI-driven VR simulations train dental staff in new technologies, patient management, and emergency handling. Together, AI, VR, and AR are paving the way for a more precise, immersive, and patient-centered approach to oral healthcare, transforming both education and clinical practice.

Conclusion

Transforming dentistry requires a comprehensive approach that integrates technology, community engagement, education, and policy reforms to enhance

access, equity, and outcomes in oral healthcare. Advanced technologies such as artificial intelligence (AI), virtual reality (VR), augmented reality (AR), and data-driven tools hold the potential to revolutionize diagnosis, treatment planning, and patient education by enabling proactive and personalized care.

Expanding preventive initiatives, improving oral health literacy, and addressing social determinants of health are essential steps to bridge disparities, particularly in underserved communities. Furthermore, the integration of medical and dental electronic health records (EHRs) through interoperable systems and AI-powered analytics can redefine healthcare delivery. This integration promotes holistic care, drives impactful research, and facilitates data-driven insights to improve patient outcomes.

However, realizing the full potential of these advancements requires addressing key challenges such as establishing interoperability standards, ensuring robust privacy protections, and fostering system adaptability and adoption. By overcoming these barriers, dentistry can advance toward a future of equitable and innovative oral healthcare.

References

1. Acharya A, Schroeder D, Schwei K, Chyou P-H. Update on electronic dental record and clinical computing adoption among dental practices in the United States Clin Med Res 201715(3–4):59–74
2. Adnan K, Akbar R, Khor SW, Ali ABA. 2020. Role and challenges of unstructured big data in healthcare. In: Sharma N, Chakrabarti A, Balas VE. editors. Data management, analytics and innovation. Vol. 1042. Singapore: Springer Singapore; p. 301–323. doi: 10.1007/978-981-32-9949-8_22
3. Bates, C., & Bates, C. (2020, July 2). Understanding Interoperability in Healthcare and Dentistry - Exan Software. Exan Software - Academic Dental Software. https:// www. exansoftware. com/ understanding-interoperability-in-healthcare-and-dentistry/
4. Dental data exchange hits milestone with successful sharing of full record. (2024).Ada.org. https:// adanews.ada.org/ada-news/2024/october/dental-data-exchange-hits-milestone-with-successful-sharing-of-full-record/
5. Directorate-General for Informatics (European Commission). (2017). New European interoperability framework: promoting seamless services and data flows for European public administrations. In Publications Office of the European Union. Publications Office of the European Union. https:// op.europa.eu/en/publication-detail/-/publication/ bca 40dde-deee-11e7-9749-01aa75ed71a1/language-en
6. Geraci A. 1991. IEEE standard computer dictionary: compilation of IEEE standard computer glossaries. Piscataway (NJ): IEEE Press
7. Glick, M. (2015). Taking a byte out of big data. The Journal of the American Dental Association, 146(11), 793–794. https://doi.org/ 10.1016/ j.adaj. 2015.09.002
8. IHE Publications. (2025). Ihe.net. https:// profiles. ihe.net/
9. Joda T, Waltimo T, Probst-Hensch N, Pauli-Magnus C, Zitzmann NU. 2019. Health data in dentistry: an attempt to master the digital challenge. Public Health Genomics. 22(1–2): 1–7
10. Joda T, Yeung AWK, Hung K, Zitzmann NU, Bornstein MM. 2021. Disruptive innovation in dentistry: what it is and what could be next. J Dent Res. 100(5):448–453
11. Jones KH, Laurie G, Stevens L, Dobbs C, Ford DV, Lea N. 2017. The other side of the coin: harm due to

the non-use of health-related data. Int J Med Inform. 97:43–51

12. Kalenderian E, Walji M, Ramoni RB. 2013. "Meaningful use" of EHR in dental school clinics: how to benefit from the US HITECH Act's financial and quality improvement incentives. J Dent Educ. 77(4):401–415
13. Lancet Editorial. 2018. Making sense of our digital medicine Babel. Lancet. 392(10157):1487
14. Liang H, Tsui BY, Ni H, Valentim CCS, Baxter SL, Liu G, Cai W, Kermany DS, Sun X, Chen J, et al. 2019. Evaluation and accurate diagnoses of pediatric diseases using artificial intelligence. Nat Med. 25(3):433–438
15. Lye C T, Forman H P, Daniel J G, Krumholz H M. The 21st Century Cures Act and electronic health records one year later: will patients see the benefits? J Am Med Inform Assoc. 2018;25(09):1218–1220. doi: 10.1093/jamia/ocy065
16. Mennemeyer S T, Menachemi N, Rahurkar S, Ford E W. Impact of the HITECH Act on physicians' adoption of electronic health records. J Am Med Inform Assoc. 2016;23(02):375–379. doi: 10.1093/jamia/ocv103
17. Improving Oral-Systemic Healthcare through the Interoperability of Electronic Medical and Dental Records: An Exploratory Study | Resource Library for the Integration of Oral Health and Medicine. (2019). Harvard.edu. https:// resourcelibrary. hsdm. harvard.edu/publications/improving-oral-systemic-healthcare-through-interoperability
18. Neel Shimpi, Buchanan, E., & Acharya, A. (2022). How Medical-Dental EHR Integration Can Improve Diabetes Care. AMA Journal of Ethics, 24(1), 99–105. https://doi.org/10.1001/amajethics.2022.99
19. Obadan-Udoh E, Simon L, Etolue J, Tokede O, White J, Spallek H, Walji M, Kalenderian E. 2017. Dental providers' perspectives on diagnosis-driven dentistry: strategies to enhance adoption of dental diagnostic terminology. Int J Environ Res Public Health. 14(7):767
20. Obermeyer Z, Emanuel EJ. 2016. Predicting the future—big data, machine learning, and clinical medicine. N Engl J Med. 375(13):1216–1219
21. Pedro, Martín-Martín, D., & Romero, I. (2024). Digital Transformation of Oral Health Care: Measuring the Digitalization of Dental Clinics. Social Indicators Research. https://doi.org/ 10.1007/s11205-024-03366-z
22. Perlin JB. 2016. Health information technology interoperability and use for better care and evidence. JAMA. 316(16):1667–1668
23. Rajkumar, N. M. R., Muzoora, M. R., & Thun, S. (2022). Dentistry and Interoperability. Journal of Dental Research, 101(11), 1258–1262. https:// doi.org/ 10.1177/00220345221100175
24. Rangoli Srivastava, Dr. Pradeep Tangade, & Dr. Surbhi Priyadarshi. (2023). Transforming public health dentistry: Exploring the digital foothold for improved oral healthcare. 11(2), 61–67. https://doi.org/10.18231/j.idjsr.2023.013
25. Simon, L., Obadan-Udoh, E., Yansane, A.-I., Gharpure, A., Licht, S., Calvo, J., Deschner, J., Damanaki, A., Hackenberg, B., Walji, M., Spallek, H., & Kalenderian, E. (2019). Improving Oral–Systemic Healthcare through the Interoperability of Electronic Medical and Dental Records: An Exploratory Study. Applied Clinical Informatics, 10(03), 367–376. https://doi.org/ 10.1055/s-0039-1688832

26. Studeny J, Coustasse A. Personal health records: is rapid adoption hindering interoperability? Perspect Health Inf Manag. 2014;11:1e
27. Tokede O, White J, Stark PC, Vaderhobli R, Walji MF, Ramoni R, Schoonheim-Klein M, Kimmes N, Tavares A, Kalenderian E. 2013. Assessing use of a standardized dental diagnostic terminology in an electronic health record. J Dent Educ. 77(1):24–36
28. Topol EJ, Steinhubl SR, Torkamani A. 2015. Digital medical tools and sensors. JAMA. 313(4):353–354
29. Weinert, L., Listl, S., Dannewitz, B., Heinze, O., Mostovic, T., Kalmus, O., & El Sayed, N. (2022). Engaging patients to develop a customized digital health companion for periodontitis: Study protocol. Frontiers in Oral Health, 3. https://doi.org/10.3389/froh.2022.1004091
30. What Do We Mean by Interoperability in Oral Health? (2024). CareQuest Institute for Oral Health. https://www.carequest.org/about/blog-post/what-do-we-mean-interoperability-oral-health