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Research Article

# A Systematic Review on Use of Blockchain Technology Across Different Domains of Dentistry

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ABSTRACT

Blockchain technology has emerged as a promising solution for enhancing data security, privacy, and interoperability across various sectors, including healthcare. In dentistry, its adoption holds the potential to revolutionize dental practice and management. However, a thorough examination of the available literature concerning the integration of blockchain technology in dental practice is lacking. This systematic review sought to evaluate the current evidence regarding the implementation of blockchain technology in dental practice and management. Through a systematic search of major databases using relevant keywords related to blockchain technology and dentistry, studies meeting the inclusion criteria were identified. Adhering to the PRISMA guidelines, studies reporting on the implementation, adoption, and outcomes of blockchain technology in dental practice and management were included. Quality assessment and data extraction were conducted based on predefined criteria. Despite initially yielding a large number of articles, the application of inclusion and exclusion criteria resulted in the inclusion of six studies in the systematic review. These studies examined various facets of blockchain technology implementation in dental practice, such as data security, interoperability, supply chain management, and patient consent management. Moreover, they highlighted the potential benefits of blockchain-based systems in improving efficiency in supply chain management and authenticating patient consent. Overall, this systematic review shed light on the current status of blockchain technology implementation in dental practice and management. It indicated that blockchain technology has the capacity to enhance data security, privacy, and interoperability within dental practices. However, further research and real-world implementation endeavors are essential to fully grasp the impact of blockchain technology on dental practice and to address the existing challenges.

## INTRODUCTION

Blockchain technology functions as a decentralized and immutable database that streamlines asset tracking and transaction recording within a corporate network. It comprises a growing series of records, termed blocks, securely linked together through encryption. Each block contains transaction details, a timestamp, and a cryptographic hash of the previous block. The timestamp confirms the presence of transaction data at the block's creation. These blocks form a chain by storing information about preceding blocks, establishing interconnectivity. Consequently, once a transaction is recorded, it becomes irreversible without altering subsequent blocks, ensuring the permanence of blockchain transactions[1-5].

Decentralization is a key aspect of blockchain technology, where there is no central authority controlling the addition of content to the blockchain. Instead, entries are verified by the peer-to-peer network and follow various consensus mechanisms. Data security is a major focus in blockchain transactions, as transfers occur directly through the blockchain without intermediaries, reducing the risk of data breaches or tampering. Persistence is another important feature of blockchain, as once entries are added to the blockchain, they become unchangeable due to the distributed ledger across multiple nodes. Moreover, many blockchains offer pseudonymity, where users' identities are protected[6, 7]. **Figure 1** outlines the main characteristics of blockchain technology. Auditability and traceability are key features of blockchain, allowing new blocks to be linked to previous ones, forming a chain of blocks. Transactions within blocks are organized using a Merkle tree structure, where each leaf value is verified, leading to the root. This approach enables blockchain to maintain the integrity of the tree structure and validate it[8].

The core concepts of blockchain technology (BCT) and its utilization in the healthcare field, specifically its importance in handling sensitive

medical data, are crucial topics. Considering the significance of progress in healthcare for societal welfare, the utilization of computational technologies can effectively tackle significant challenges within this industry. Informatics holds a key position in streamlining medical records, guaranteeing secure data exchange, maintaining comprehensive log records, and fulfilling other critical functions[9-11].

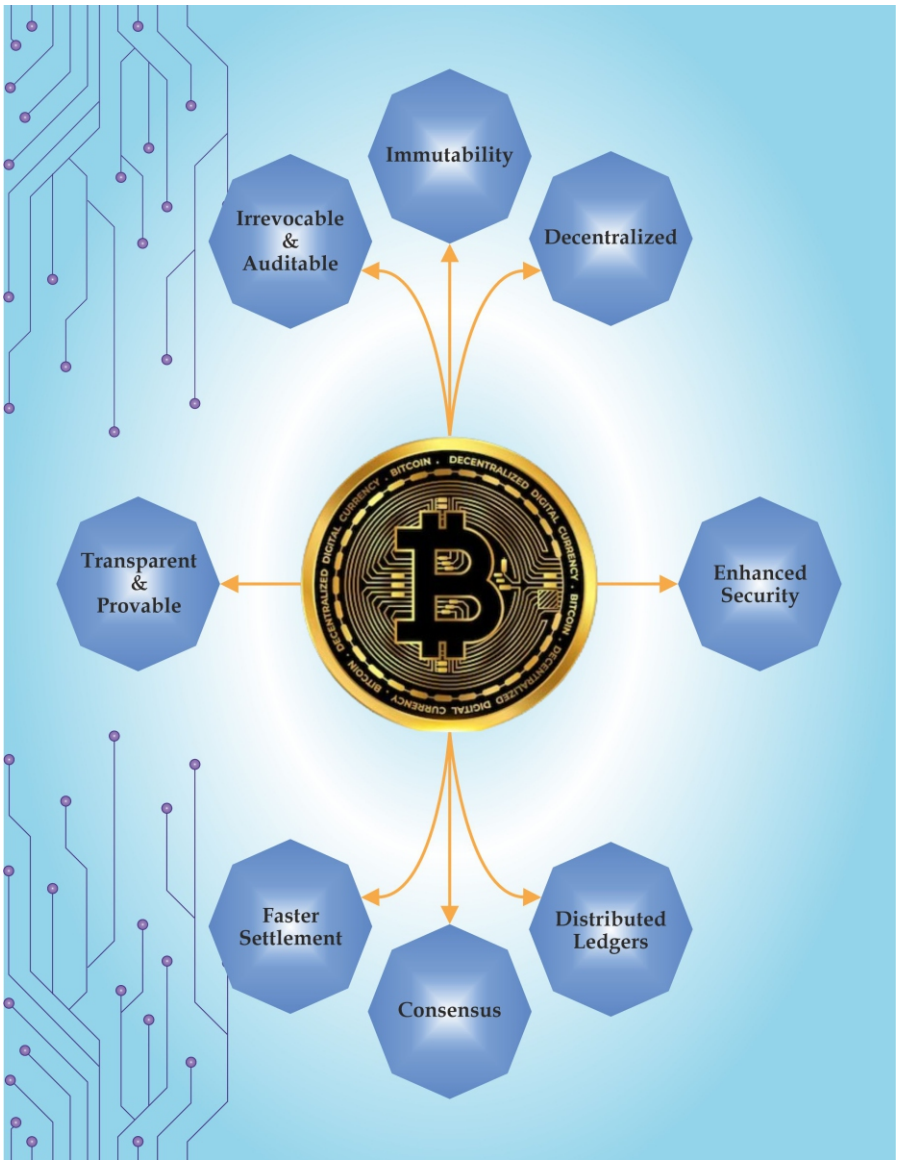


**Figure 1: Essential Characteristics of Blockchain Technology [7, 9].**

One of the earliest and most notable uses of blockchain technology in healthcare is the exchange of health records. Due to the sensitive nature of health information, blockchain-based systems offer various features to securely share electronic healthcare records [12]. Traditional voting methods are centralized and vulnerable to security and efficiency issues. Blockchain-based voting systems, as discussed in recent research, offer improved security and efficiency by categorizing them based on different types of blockchains, consensus approaches, and participant scales. Artificial Intelligence (AI) plays a crucial role in numerous applications, including smart healthcare, which is a key component of smart cities [13]. Research efforts, such as those mentioned in recent studies, focus on safeguarding patient privacy in smart healthcare through innovative schemes involving human-in-the-loop assistance. Privacy concerns also arise in medical data sharing facilitated by Internet of Medical Things (IoMT) technologies. To tackle this issue, studies propose schemes like verifiable private set intersection to maintain patient privacy during profile matching. While technologically advanced countries explore implementations of smart home systems, current solutions based on single-server architecture have limitations in terms of privacy and integrity. Blockchain-based solutions, although promising, encounter various obstacles [14, 15]. Sharing information represents a significant opportunity for enhancing healthcare outcomes, albeit accompanied by substantial privacy challenges. **Figure 2** illustrates the proce-

-ss of data sharing utilizing Blockchain Technology (BCT) [16].

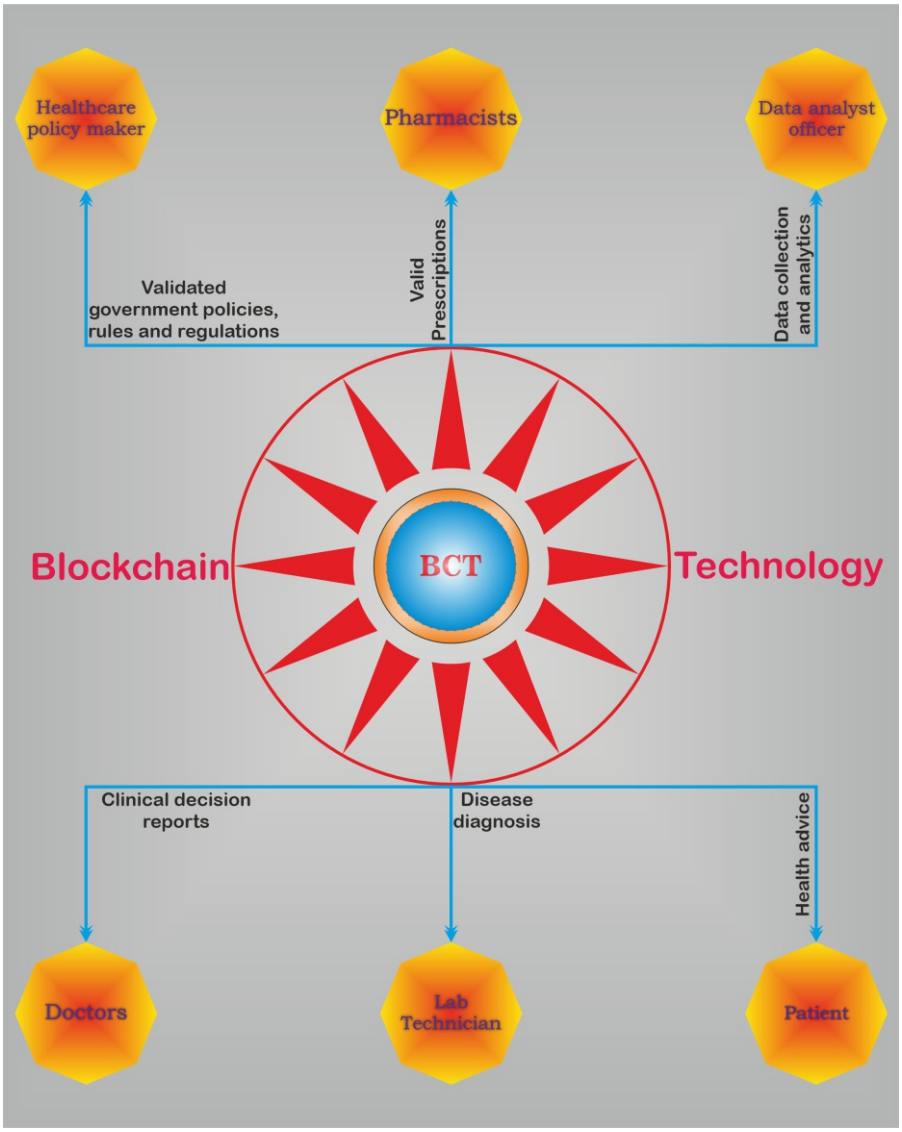


**Figure 2: Utilizing Blockchain Technology (BCT) for the sharing of health information [9].**

Enhancing the management of trial subject consent and the overall clinical trial process represents an area where blockchain technology shows considerable potential. It offers opportunities to improve the accountability, auditability, and transparency of medical practitioners and researchers. By maintaining an unalterable record of patient approvals, blockchain technology enables authorities to better oversee the integrity of clinical trials, ensuring adherence to informed consent regulations. This is especially critical given the prevalence of falsified informed consent forms, which constitute a common form of clinical fraud involving the manipulation of patient consent and record alteration. Therefore, ensuring the authentication of trial sub--jects is essential for mitigating such risks[17-19].

The implementation of a smart contract system presents a promising approach to addressing these challenges. Such a system would restrict clinicians from accessing patient data unless a key is issued at the conclusion of an auditable smart contract process, which requires permission at each step of the trial. Additionally, it should facilitate the revocation of patient consent when necessary. By adopting a blockchain-based consent log for clinical trials, not only do subjects gain ownership of their data, but it also establishes an audit trail for regulators, medical professionals, and researchers. This visual representation of the role of blockchain technology in clinical trials is depicted in **Figure 3** [20-22].

The benefits of integrating blockchain technology into dentistry are diverse. Initially, blockchain's decentralized nature eliminates the necessity for a central authority, ensuring data integrity and reducing the risk of unauthorized access or manipulation. Secondly, the utilization of smart contracts and cryptographic techniques has the potential to

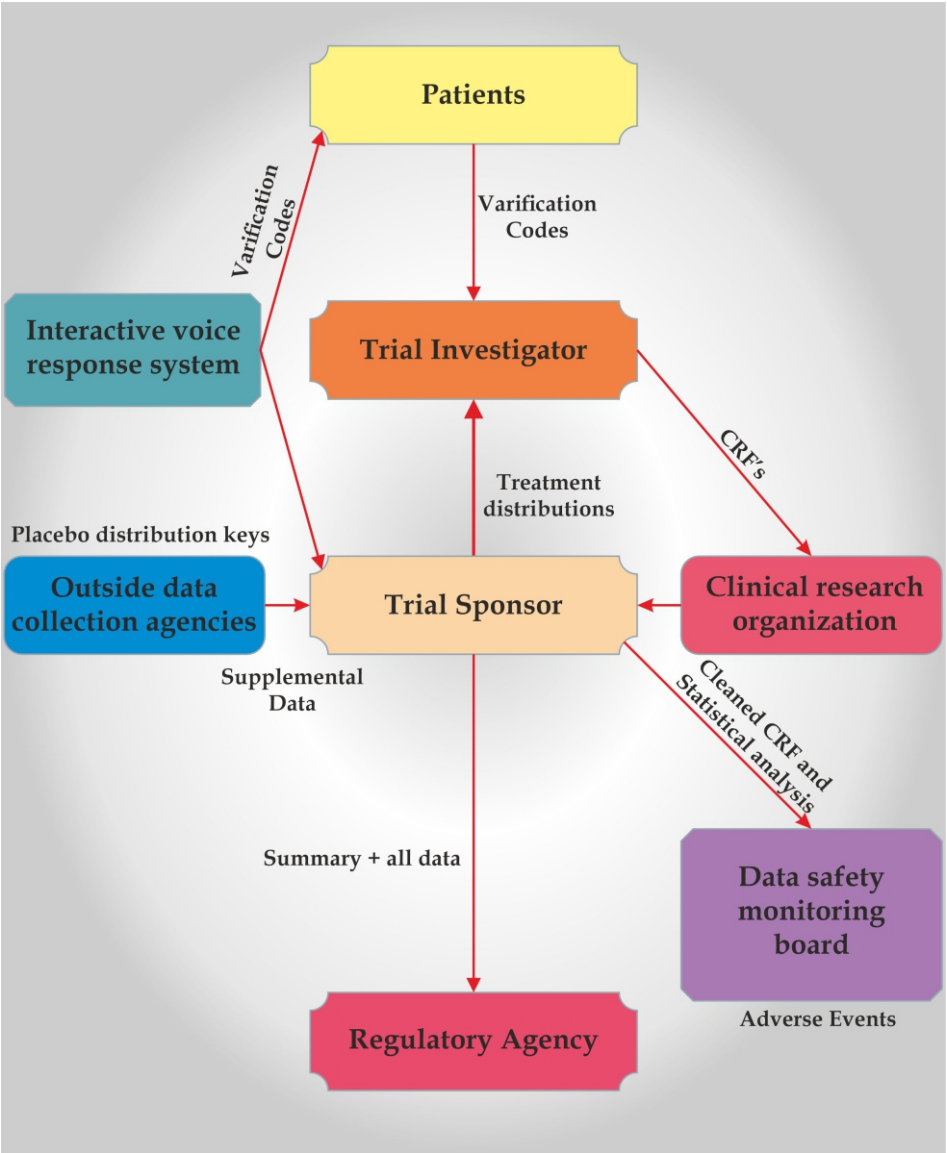


**Figure 3: Function of blockchain in clinical trials [9].**

enhance patient privacy and consent management by empowering patients to control their health information. Moreover, blockchain facilitates interoperability among different dental systems and ensures secure data exchange, thereby improving care coordination and treatment outcomes [23-25]. However, despite its potential, implementing blockchain technology in dentistry comes with challenges. Technical issues such as scalability, energy consumption, and compatibility with existing infrastructure pose significant obstacles that must be addressed for practic--al adoption. Additionally, establishing regulatory frameworks to address data privacy and security concerns is crucial to align blockchain technology with the legal requirements of dentistry. Furthermore, considerations related to costs and the implementation of effective governance mechanisms add to the complexity of adoption. Therefore, it is essential to conduct a comprehensive assessment of the current state of blockchain technology implementation across various domains of dentistry to better understand its potential benefits and challenges. **Figure 4** illustrating the primary areas of application for Blockchain Technology (BCT) within the healthcare industry.[26, 27].

The aim of this systematic review is to thoroughly examine and synthesize the existing understanding of incorporating blockchain technology across different facets of dentistry. Specifically, the review will explore the various uses of bloc-blockchain in dental practice, analyze both the benefits and challenges associated with its adoption, and evaluate its potential impact on aspects such as data handling, patient privacy, treatment efficacy, and operational effectiveness. Through this comprehensive analysis, the review seeks to provide valuable insights into the present state and future prospects of integrating blockchain technology within the dental field.

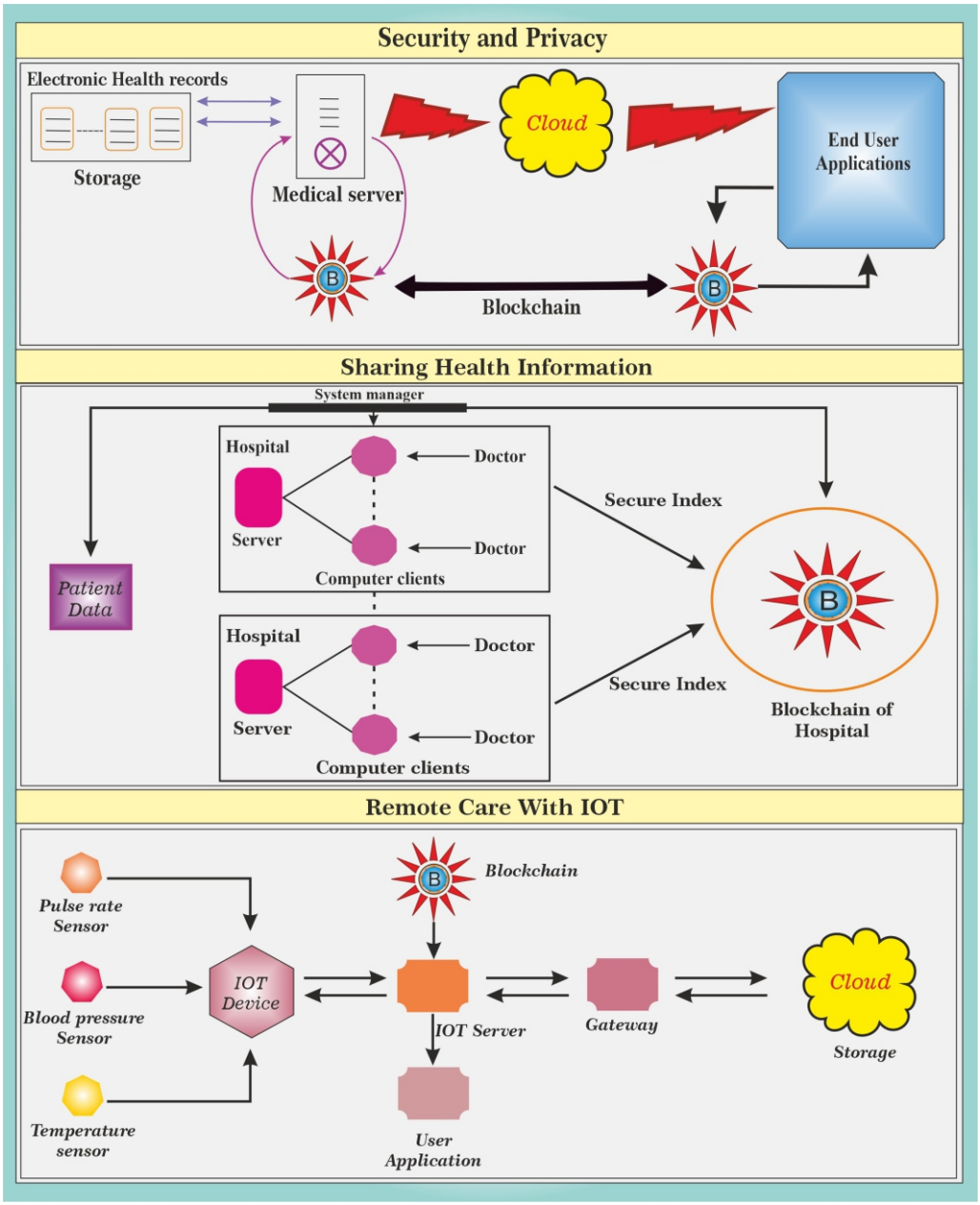


**Figure 4: Primary areas within the healthcare industry where Blockchain Technology (BCT) has been applied [9].**

**Review**

This systematic review strictly adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol. The PRISMA guidelines served as a robust framework for transparently reporting the findings of the systematic review, thereby ensuring the inclusion of pertinent information and bolstering the study's reproducibility. **Figure 5** illustrates the application of PRISMA guidelines in this review.

**Search strategy**

A thorough search strategy was employed, utilizing electronic databases including PubMed, Scopus, Embase, Web of Science, Google Scholar, Cochrane Library, and ProQuest to identify relevant articles. The search strategy en-

-compassed keywords such as "blockchain technology," "dentistry," "dental practice," "patient data," "privacy," "treatment outcomes," and "practice management." Boolean operators and Medical Subject Headings (MeSH) terms were utilized to refine the search and guarantee the inclusion of pertinent studies.

**Inclusion and exclusion criteria**

Predetermined inclusion and exclusion criteria were set to direct the selection of studies in this systematic review. The inclusion criteria covered studies investigating the use of blockchain technology in various aspects of dentistry, including clinical practice, patient data management, treatment outcomes, and practice administration. Empirical studies, case studies, and systematic reviews were considere-


**Figure 5: PRISMA protocol for this review**

-ed for inclusion if they provided relevant insights into how blockchain technology is applied in dentistry. Conversely, studies that did not directly focus on the implementation of blockchain technology in dentistry and articles written in languages other than English were excluded from the review process.

**Data extraction protocol**

A standardized protocol for data extraction was developed to systematically retrieve relevant information from the chosen studies. This protocol streamlined the process of capturing essential details from each study, including study attributes (such as authors and publication year), methodology (including study design and sample size), applications of blockchain in dentistry, reported results, identified advantages, encountered obstacles, and recommendations made by the authors. By adhering to this structured method, consistency was ensured throughout the data extraction process, facilitating a comprehensive analysis of the collected data.

**Bias assessment**

The assessment of bias for this systematic review utilized the Joanna Briggs Institute (JBI) checklist, a recognized tool for evaluating bias in systematic reviews. This checklist ensured the methodological robustness of the review process and assessed each included study against seven criteria: study design, sampling strategy, data collection methods, appropriateness of data analysis, clarity of reporting, ethical considerations, and potential conflicts of interest. In terms of study design, the four included studies employed various research designs, such as case studies and qualitative studies, providing valuable insights into blockchain technology in dental practice. However, these designs may be prone to biases like selection bias and response bias. Sampling strate-

-gies varied among the studies, potentially impacting the representativeness of the samples and introducing bias. Data collection methods were generally well-described across the included studies, utilizing interviews, surveys, and document analysis. However, some studies lacked sufficient detail, which could affect the reliability and validity of the findings. Data analysis approaches were generally appropriate, including thematic and statistical analyses where applicable. Reporting in the included studies was clear and comprehensive, although some lacked information on limitations and alternative interpretations, possibly introducing reporting bias. Ethical considerations were addressed in most studies, with approvals and consent procedures outlined. No conflicts of interest were reported in any of the included studies.

**DISCUSSION**

Drawing from the current literature, it was postulated that incorporating blockchain technology into dentistry could yield benefits such as bolstering data security, safeguarding patient privacy, improving treatment efficacy, and streamlining practice operations. Nevertheless, it was foreseen that hurdles such as technological limitations,regulatory hurdles, and the need for extensive personnel training across various stakeholders like hospitals, patients, and insurance providers might hinder the widespread acceptance of blockchain technology within the dental field. This systematic review aimed to meticulously evaluate the existing evidence to provide a holistic insight into both the potentials and obstacles associated with integrating blockchain technology into dentistry[23, 25, 28].

In the initial phase of this systematic review, an extensive search was conducted to identify relevant articles exploring the application of blockchain technology in various domains of dentistry. Initially, a total of 850 articles were retrieved thr-

-ough this search process.These articles then underwent a rigorous screening process based on predefined criteria for inclusion and exclusion. This screening involved evaluating the titles, abstracts, and full texts to determine their relevance to the research question. Following this thorough screening process, six papers were selected for inclusion in the systematic review based on their alignment with the research objectives, topical relevance, and methodological quality. These six papers were deemed to provide valuable insights and evidence on the utilization of blockchain technology within different aspects of dentistry. Only those papers that met the specified inclusion criteria and addressed key aspects of blockchain implementation in dental practice and management were included in the final review. The studies enumerated in Table 2 offered diverse insights into the implementation of blockchain technology across various domains of dentistry. Particularly, the findings highlighted the potential of blockchain technology to significantly enhance the practice of radiography in oral and maxillofacial surgery (OMFS)[29, 30].

This technology has the potential to enhance data security and privacy, which is particularly crucial in the field of radiography. It was emphasized how important it is for radiology technologists and oral and maxillofacial radiologists to familiarize themselves with blockchain technology and its applications. Moreover, there was a suggestion for the development of an online dental database capable of managing dental cast models and dental identity data. Such a database could assist in locating missing persons by comparing postmortem dental artifacts with dental records, demonstrating the potential of blockchain technology in improving dental identification systems. Additionally, attention was given to the virtual dental home model as a solution to improve access to dental care and oral health for vulnerable and underserved groups. The success of the current demonstration has led to an increased demand for this model, which could be further facilitated by blockchain technology[31-33].

Another observation underscored the need for an integrated access control system that supports patient-centric protocols and ensures privacy protection requirements are met. The importance of selectively sharing virtual composite Electronic Health Records (EHRs) was emphasized, taking into account factors such as the integration of dispersed data and privacy considerations. Additionally, the use of blockchain-enabled interplanetary file system (Block-IPFS) was acknowledged as a secure method for transferring imaging data for Artificial Intelligence (AI) research in oral and maxillofacial surgery (OMFS), highlighting the criticality of data privacy, storage, and secure exchange in AI research contexts [34]. Furthermore, the proposition to integrate digital technologies into dental workflows aimed to enhance treatment effectiveness, underlining the necessity f-

-or dental professionals to possess the requisite knowledge and skills to choose and effectively utilize digital technologies in their practices. These findings collectively suggest that blockchain technology has the potential to address significant challenges in dentistry, including data security, privacy, interoperability, and access to care. While indicating the potential enhancement of various aspects of dental practice and management, further research and real-world implementation studies are essential to comprehensively understand the impact and overcome the challenges associated with integrating blockchain technology in dentistry[35-39].

This study significantly contributes to advancing our understanding of implementing blockchain technology across various domains within dentistry. The insights gleaned from the systematic review provide valuable perspectives on the potential benefits and challenges associated with adopting blockchain technology in dental practice and management. Firstly, the findings underscore how blockchain technology has the potential to enhance data security, privacy, and interoperability in dental practices[40]. By leveraging blockchain's decentralized and immutable nature, dental professionals can ensure the security of patient data, protect patient privacy, and facilitate seamless information sharing among different healthcare providers and systems. This has the potential to improve patient outcomes, streamline workflows, and promote collaboration among dental practitioners. Secondly, the review identifies specific areas within dentistry where blockchain technology can bring about transformative changes. These include oral and maxillofacial surgery (OMFS), dental identification systems, dental clinic administration, and dental workflow. Understanding the potential applications of blockchain in these domains can inform future research and innovation efforts, enabling the development of customized solutions to address specific needs and challenges within these areas[41-43].

Furthermore, the review underscores the significance of dental professionals and radiology technologists acquiring a thorough understanding of blockchain technology and its potential applications. With blockchain continuously evolving and becoming integrated into healthcare systems, it is imperative for dental practitioners to remain updated on the latest advancements. This knowledge empowers them to make well-informed decisions regarding the adoption and integration of blockchain solutions into their practices, ultimately improving patient care and outcomes. It serves as a foundational resource for further research and implementation endeavors in the field of blockchain technology in dentistry. Subsequent studies can build upon the insights gleaned from this review to explore practical aspects of implementing blockchain solutions, including technical considerations, regulatory frameworks, and cost-e-

-ffectiveness. Additionally, the challenges identified, such as technological barriers and privacy concerns, can guide the development of strategies and best practices to overcome these obstacles and ensure the successful implementation of blockchain technology in dental practice[43, 44].

Bayrakdar et al. conducted an editorial review focusing on exploring the potential advancements that blockchain technology could bring to the field of radiography within oral and maxillofacial surgery (OMFS). The authors aimed to investigate how blockchain technology could significantly advance radiography in OMFS. Their conclusion suggested that blockchain technology had the potential to notably improve the practice of radiography in OMFS. They emphasized the importance of radiology technologists and oral and maxillofacial radiologists being knowledgeable about both current and potential future applications of this technology[33].

Bholsithi et al. conducted an in-vitro study that evaluated the absence of a database capable of managing dental cast models and dental identity data for further dental research. Their objective was to develop an online dental database capable of meticulously recording dental identification data from individual teeth and overall dental structure to aid in locating missing persons. Their conclusion highlighted the significance of such a database in facilitating the comparison of postmortem dental artifacts with dental records, thereby assisting in the identification of missing individuals[45].

Glassman et al. conducted a literature review focusing on the management of dental clinic-related services. Their objective was to assess oral health systems to improve the care experience, enhance population health, and reduce healthcare costs per capita. Their review revealed a growing demand for the virtual dental home model as the success of the current demonstration gained recognition and spread among individuals interested in enhancing access to dental care and oral health for vulnerable and underserved populations[46].

Jin et al. conducted a literature review on the management of dental clinic-related services. Their aim was to propose an integrated access control system supporting patient-centric protocols, data aggregation, and privacy protection requirements. Their conclusion suggested an innovative approach to facilitate authorized and selective sharing of virtual composite Electronic Health Records (EHRs), considering factors such as dispersed data integration and privacy concerns[47].

Orhan et al. conducted an editorial review focusing on OMFS and the potential of Block-IPFS in securely transferring imaging data for AI research in OMFS. Their conclusion underscored the importance of data privacy, storage, and secure exchange in the context of the increasing AI research. They emphasized the necessity for radiology technologists and oral and maxillofacial radiologists to unde--rstand both current and potential future applications of blockchain technology[48].

Valizadeh et al. conducted a literature review examining the dental workflow and its components, particularly the interconnections between dental offices, labs, and production facilities in performing treatments using software and digital hardware equipment. Their conclusion suggested embracing digital technologies to improve the effectiveness of treatments. They encouraged stakeholders in the field to acquire the necessary knowledge to effectively select and utilize these technologies[49].

The incorporation of blockchain technology into healthcare shows potential for enhancing security, privacy, access control, and decentralized data sharing, presenting both opportunities and challenges that warrant attention from the research community. However, the existing literature on blockchain implementation in dental care reveals numerous limitations and constraints. One such constraint is the block-size limitation, which hinders the effective storage of textual records in the blockchain ledger [50]. While theoretical methods for storing dental images have been proposed, practical experimentation is necessary to verify the reliability of such systems. Additionally, scalability, interoperability, transaction throughput, and latency assessment are critical concerns that require thorough evaluation. Many studies propose blockchain-based dental care systems without conducting comprehensive analyses of the proposed solutions. Assessing scalability and transactional latency is essential as the network expands with more nodes (dental clinics) and increased data/transaction volumes. Furthermore, exploring the potential impact of input/output operations and smart contract limitations on transaction latency is crucial for identifying areas for further research[51-53].

Moreover, many of the examined articles adopt a theoretical stance without putting the proposed systems into practice, which could result in overly positive conclusions and inadequate consideration of communication delays. Future endeavors should prioritize practical implementations and tackle specific challenges associated with utilizing blockchain in healthcare, vehicular networks, and wireless networks. Additionally, the absence of a robust blockchain framework for healthcare poses a notable barrier to its widespread adoption. The integration of blockchain-based patient health records with existing systems requires substantial restructuring, staff training, and the persuasion of stakeholders regarding the value and feasibility of blockchain technology [54, 55]. Health-related companies play a pivotal role in facilitating short-term system enhancements while laying the groundwork for a successful implementation of blockchain in healthcare. Tackling these constraints and obstacles will be crucial for the future advancement and acceptance of blockchain technology in b-

oth dental care and the broader healthcare sector. Persistent research, tangible applications, and cooperation among researchers, healthcare professionals, and policymakers will be essential in fully harnessing the capabilities of blockchain technology to improve patient results, streamline data handling, and enhance overall efficiency in healthcare operations[56].

Despite the valuable insights gleaned from this study regarding the incorporation of blockchain technology in dentistry, it is crucial to recognize and address its limitations. These limitations offer context for interpreting the findings and underscore areas necessitating further investigation and consideration[57]. Firstly, a constraint of this study lies in the limited number of included studies. The systematic review identified a relatively modest quantity of studies meeting the inclusion criteria, potentially restricting the generalizability and comprehensiveness of the findings. The dearth of available literature on the subject underscores the necessity for additional research in this domain to establish a broader and more robust evidence base. Secondly, the heterogeneity among the included studies presents another limitation. These studies spanned various domains of dentistry and employed different blockchain technology modalities, making it challenging to draw conclusive results or conduct a meta-analysis [58]. The varied nature of the studies underscores the need for standardized methodologies and consistent reporting practices in future research to facilitate improved comparisons and synthesis of findings. Furthermore, the quality and risk of bias inherent in the included studies may impact the reliability and validity of the findings. While the systematic review utilized predefined criteria for quality assessment, it is essential to acknowledge that the quality of individual studies can influence the overall strength of evidence. Studies with potential biases or methodological limitations may introduce uncertainties in the findings, warranting careful interpretation [59]. Another limitation is the focus solely on English-language publications, potentially introducing language bias. By excluding non-English studies, relevant research conducted in other languages may have been overlooked, potentially constraining the comprehensiveness of the review. Incorporating studies from a broader linguistic spectrum could offer a more comprehensive understanding of global perspectives on the implementation of blockchain technology in dentistry. Lastly, it is imperative to acknowledge the rapidly evolving nature of the field of blockchain technology in dentistry. The studies included in this review reflect the state of the field at the time of their publication, but technological advancements and new research may have emerged subsequently. Therefore, the findings of this review may not fully encompass the latest developments in the field, necessitating ongoing updates and future studies to stay abreast of advancements in blockchain technology[23].

## CONCLUSION

The results indicate that blockchain technology shows potential for enhancing various aspects of dental practice, including data security, privacy, interoperability, and efficiency. The studies examined in this review illustrated the possible advantages of blockchain technology in domains such as data management, supply chain management, patient identification, and streamlining dental workflows. However, it is essential to recognize the limitations inherent in the included studies, such as the limited number of studies and their heterogeneity. Therefore, the findings of this review should be interpreted cautiously, considering potential biases and methodological constraints in individual studies. Additionally, given the dynamic nature of blockchain technology and the ongoing need for research, this review underscores the importance of future investigations. Future studies should strive to address the identified limitations, standardize methodologies, enhance the quality of evidence, and explore novel applications of blockchain technology in dentistry. With continued research efforts and advancements, blockchain technology holds the potential to transform dental practice, enhance patient outcomes, and drive innovation in the dental industry as a whole.

## AVAILABILITY OF DATA AND MATERIAL

Not Applicable.

## CONFLICT OF INTERESTS

Authors declared that there is no conflict of interest.

## FUNDING

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## REFERENCES

1. Dong, S., et al., *Blockchain technology and application: an overview.* PeerJ Comput Sci, 2023. **9**: p. e1705.
2. Dutta, P., et al., *Blockchain technology in supply chain operations: Applications, challenges and research opportunities.* Transp Res E Logist Transp Rev, 2020. **142**: p. 102067.
3. Singh, Y., et al., *Exploring applications of blockchain in healthcare: road map and future directions.* Front Public Health, 2023. **11**: p. 1229386.
4. Albshaier, L., S. Almarri, and M.M. Hafizur Rahman, *A Review of Blockchain's Role in E-Commerce Transactions: Open Challenges, and Future Research Directions.* Computers, 2024. **13**(1): p. 27.
5. Rahman, F., C. Titouna, and F. Nait-Abdesselam, *Fundamentals of Blockchain and Smart Contracts*, in *Blockchain and Smart-Contract Technologies for Innov-*

*-ative Applications*, N. El Madhoun, I. Dionysiou, and E. Bertin, Editors. 2024, Springer Nature Switzerland: Cham. p. 3-37.

6. Zarrin, J., et al., *Blockchain for decentralization of internet: prospects, trends, and challenges.* Cluster Computing, 2021. **24**(4): p. 2841-2866.
7. Shi, S., et al., *Applications of blockchain in ensuring the security and privacy of electronic health record systems: A survey.* Comput Secur, 2020. **97**: p. 101966.
8. Bosona, T. and G. Gebresenbet, *The Role of Blockchain Technology in Promoting Traceability Systems in Agri-Food Production and Supply Chains.* Sensors (Basel), 2023. **23**(11).
9. Saeed, H. and H. Malik, *Blockchain technology in healthcare: A systematic review.* 2022. **17**(4): p. e0266462.
10. Elangovan, D. and C.S. Long, *The Use of Blockchain Technology in the Health Care Sector: Systematic Review.* 2022. **10**(1): p. e17278.
11. Ahmad, S.S., S. Khan, and M.A. Kamal, *What is Blockchain Technology and its Significance in the Current Healthcare System? A Brief Insight.* Curr Pharm Des, 2019. **25**(12): p. 1402-1408.
12. Srivastava, S. and M. Pant, *Analyzing the Prospects of Blockchain in Healthcare Industry.* 2022. **2022**: p. 3727389.
13. Lee, H.A. and H.H. Kung, *An Architecture and Management Platform for Blockchain-Based Personal Health Record Exchange: Development and Usability Study.* 2020. **22**(6): p. e16748.
14. Amanat, A., et al., *Blockchain and cloud computing-based secure electronic healthcare records storage and sharing.* Front Public Health, 2022. **10**: p. 938707.
15. Upadrista, V., S. Nazir, and H. Tianfield, *Secure data sharing with blockchain for remote health monitoring applications: a review.* Journal of Reliable Intelligent Environments, 2023. **9**(3): p. 349-368.
16. Elvas, L.B. and C. Serrão, *Sharing Health Information Using a Blockchain.* 2023. **11**(2).
17. Mak, B.C. and B.T. Addeman, *Leveraging Blockchain Technology for Informed Consent Process and Patient Engagement in a Clinical Trial Pilot.* 2021. **4**.
18. Jafri, R. and S. Singh, *Blockchain applications for the healthcare sector: Uses beyond Bitcoin*. Blockchain Applications for Healthcare Informatics. 2022:71-92. doi: 10.1016/B978-0-323-90615-9.00022-0. Epub 2022 Jun 17.
19. Wu, T.C. and C.B. Ho, *Blockchain Revolutionizing in Emergency Medicine: A Scoping Review of Patient Journey through the ED.* Healthcare (Basel), 2023. **11**(18).
20. Vargas, C. and M. Mira da Silva, *Case studies about smart contracts in healthcare.* 2023. **9**: p. 20552076231-203571.
21. Zhuang, Y. and L. Zhang, *Promoting TEFCA with Blockchain Technology: A Decentralized Approach to Patient-centered Healthcare Data Management.* AMIA Annu Symp Proc, 2023. **2023**: p. 824-833.
22. Khatoon, A. *A Blockchain-Based Smart Contract System for Healthcare Management*. Electronics, 2020. **9**, DOI: 10.3390/electronics9010094.
23. Ingle, N.A., et al., *Implementation of Blockchain Technology Across Different Domains of Dentistry: A Systematic Review.* Cureus, 2023. **15**(9): p. e45512.
24. Sharma, V. and K.K. Meena, *Dentistry in the Digital Age: Embracing Blockchain Technology.* Cureus, 2023. **15**(5): p. e39710.
25. Mokhamed, T., et al., *The Potential of Blockchain Technology in Dental Healthcare: A Literature Review.* 2023. **23**(6).
26. Habib, G., et al. *Blockchain Technology: Benefits, Challenges, Applications, and Integration of Blockchain Technology with Cloud Computing*. Future Internet, 2022. **14**, DOI: 10.3390/fi14110341.
27. Al Amin, M., et al. *Exploring Blockchain Implementation Challenges for Sustainable Supply Chains: An Integrated Fuzzy TOPSIS–ISM Approach*. Sustainability, 2023. **15**, DOI: 10.3390/su151813891.
28. Allana, R., A. Allana, and S.S. Mahdi, *Breaking Down Barriers and Paving the Way for Blockchain Adoption in Dentistry.* Cureus, 2023. **15**(5): p. e39166.
29. Hassani, H., et al. *Revolutionary Dentistry through Blockchain Technology*. Big Data and Cognitive Computing, 2023. **7**, DOI: 10.3390/bdcc7010009.
30. Yli-Huumo, J., et al., *Where Is Current Research on Blockchain Technology?—A Systematic Review.* PLOS ONE, 2016. **11**(10): p. e0163477.
31. Tagliafico, A.S., et al., *Blockchain in radiology research and clinical practice: current trends and future directions.* Radiol Med, 2022. **127**(4): p. 391-397.
32. Ghorashi, N.S., et al., *The Intersection of Radiology With Blockchain and Smart Contracts: A Perspective.* Cureus, 2023. **15**(10): p. e46941.
33. Bayrakdar, I.S., et al., *What can Blockchain technology bring to oral and maxillofacial radiology?* Oral Surg Oral Med Oral Pathol Oral Radiol, 2020. **130**(2): p. 225-226.
34. Gariépy-Saper, K. and N. Decarie, *Privacy of electronic health records: a review of the literature.* J Can Health Libr Assoc, 2021. **42**(1): p. 74-84.
35. Tapuria, A., et al., *Impact of patient access to their electronic health record: systematic review.* 2021. **46**(2): p. 192-204.
36. de Carvalho Junior, M.A. and P. Bandiera-Paiva, *Strengthen Electronic Health Records System (EHR-S) Access-Control to Cope with GDPR Explicit Consent.* J Med Syst, 2020. **44**(10): p. 172.

37. Pawelek, J. and K. Baca-Motes, *The Power of Patient Engagement With Electronic Health Records as Research Participants.* 2022. **10**(7): p. e39145.
38. Papoutsi, C., et al., *Patient and public views about the security and privacy of Electronic Health Records (EHRs) in the UK: results from a mixed methods study.* BMC Med Inform Decis Mak, 2015. **15**: p. 86.
39. Cowie, M.R., et al., *Electronic health records to facilitate clinical research.* Clin Res Cardiol, 2017. **106**(1): p. 1-9.
40. Talaei Khoei, T., H. Ould Slimane, and N. Kaabouch, *Deep learning: systematic review, models, challenges, and research directions*. Neural Computing and Applications, 2023. **35**(31): p. 23103-23124.
41. Huang, H. and O. Zheng, *ChatGPT for shaping the future of dentistry: the potential of multi-modal large language model.* 2023. **15**(1): p. 29.
42. Odeh, A., I. Keshta, and Q.A. Al-Haija *Analysis of Blockchain in the Healthcare Sector: Application and Issues*. Symmetry, 2022. **14**, DOI: 10.3390/sym14091760.
43. AbdelSalam, F.M., *Blockchain Revolutionizing Healthcare Industry: A Systematic Review of Blockchain Technology Benefits and Threats*. Perspect Health Inf Manag. 2023 Sep 1;20(3):1b. eCollection 2023 Summer-Fall.
44. Akinola, S. and A. Telukdarie *Sustainable Digital Transformation in Healthcare: Advancing a Digital Vascular Health Innovation Solution*. Sustainability, 2023. **15**, DOI: 10.3390/su151310417.
45. Bholsithi, W., N. Phichitchaiphan, and C. Sinthanayothin. *Online dental information database for dental identification system*. in *5th International Conference on Computer Sciences and Convergence Information Technology*. 2010. IEEE.
46. Glassman, P., et al., *The virtual dental home: implications for policy and strategy.* Journal of the California Dental Association, 2012. **40**(7): p. 605-611.
47. Jin, J., et al. *Patient-centric authorization framework for sharing electronic health records*. in *Proceedings of the 14th ACM symposium on Access control models and technologies*. 2009.
48. Orhan, K., et al., *Can the blockchain-enabled interplanetary file system (Block-IPFS) be a solution for securely transferring imaging data for artificial intellgen--ce research in oral and maxillofacial radiology?* Imaging Science in Dentistry, 2021. **51**(3): p. 337-339.
49. Valizadeh, S., et al., *A review on workflow and components in digital dentistry.* Journal of Dental Medicine, 2018. **31**(2): p. 134-145.
50. Ben Fekih, R. and M. Lahami, *Application of Blockchain Technology in Healthcare: A Comprehensive Study*. The Impact of Digital Technologies on Public Health in Developed and Developing Countries. 2020 May 31;12157: 268-76. doi: 10.1007/978-3-030-51517-1_23.
51. Xie, Y. and J. Zhang, *Applications of Blockchain in the Medical Field: Narrative Review.* 2021. **23**(10): p. e28613.
52. Taherdoost, H. *Privacy and Security of Blockchain in Healthcare: Applications, Challenges, and Future Perspectives*. Sci, 2023. **5**, DOI: 10.3390/sci5040041.
53. Ali, A. and H. Ali, *Blockchain-Powered Healthcare Systems: Enhancing Scalability and Security with Hybrid Deep Learning.* 2023. **23**(18).
54. Kruk, M.E., et al., *High-quality health systems in the Sustainable Development Goals era: time for a revolution.* Lancet Glob Health, 2018. **6**(11): p. e1196-e1252.
55. Tulchinsky, T.H. and E.A. Varavikova, *Expanding the Concept of Public Health*. The New Public Health. 2014:43-90. doi: 10.1016/B978-0-12-415766-8.00002-1. Epub 2014 Oct 10.
56. Tagde, P., et al., *Blockchain and artificial intelligence technology in e-Health.* 2021. **28**(38): p. 52810-52831.
57. Ali, A., et al. *Empowering Precision Medicine: Unlocking Revolutionary Insights through Blockchain-Enabled Federated Learning and Electronic Medical Records*. Sensors, 2023. **23**, DOI: 10.3390/s23177476.
58. Peinemann, F., D.A. Tushabe, and J. Kleijnen, *Using multiple types of studies in systematic reviews of health care interventions--a systematic review.* PLoS One, 2013. **8**(12): p. e85035.
59. Ma, L.L., et al., *Methodological quality (risk of bias) assessment tools for primary and secondary medical studies: what are they and which is better?* 2020. **7**(1): p. 7.