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Original Research Article

Metaverse use in Clinical Diagnose: A systematic Review

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Abstract: ***Purpose:*** The metaverse purports to supplement these engagements by establishing 3D virtual clinics where patients and doctors can interact on a more immersive and individual level. This ability to bridge distance is essential in ensuring that outbred rural populations of patients can be linked to any specialist anywhere on the globe and hence mitigate the risk of pathogen transmission from face-to-face visits. The objective of the study is to explore the use of metaverse in clinical diagnose. ***Method***: This systematic review was conducted following the PRISMA guidelines. The major databases were systematically searched in June 2025. English-language publications from 2021 to 2025 investigating metaverse use in clinical or medicine diagnose were included. The total number of included studies that met full inclusion criteria and provided data for final qualitative synthesis was 27. Data related to these studies were systematically extracted and synthesized in order to fit the purposes of this review. ***Results:*** The healthcare metaverse represents a transformative shift toward Health 4.0, merging AI, VR, and data science to revolutionize patient care, medical education, and hospital management. By providing immersive therapeutic tools for mental and physical health, streamlining surgical planning in fields like cardiovascular medicine, and expanding global access to care, it offers a more efficient and cost-effective medical future. However, for this maturing technology to achieve widespread adoption, stakeholders must first resolve critical challenges regarding data security, interoperability, and the digital divide, while establishing validated insurance reimbursement models and regulatory frameworks to mitigate psychological risks and ensure patient safety.
Conclusion: Key opportunities in healthcare through Health 4.0 include transforming patient care with VR for therapies and enhanced medical training via immersive simulations. However, challenges exist such as the need for clinical validation, insurance models, cost barriers, and interoperability among platforms, alongside risks like data security and regulatory complexities.

Keywords: Metaverse, virtual reality, mixed reality, clinical diagnose, metaverse in medicine

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INTRODUCTION

The conceptual idea of the metaverse has existed in science fiction for some time, but is now on its way to becoming a reality that will have significant implications across a variety of sectors, including healthcare. First proposed in Neal Stephenson's 1992 novel Snow Crash, the metaverse is now being considered as the next evolution of the internet a comprehensive virtual realm that can be entered via technologies such as virtual reality (VR), augmented reality (AR) and mixed reality (MR) [1,2]. We are at the crossroads of the dawn of AI, IoT, big data analytics and high-speed 5G networks; similarly, Metaverse 's trend is growing fast in the healthcare industry as a platform for patient treatment and diagnostic innovation [3].

The most direct uses of the metaverse in medical diagnosis would be to improve telemedicine and remote consultation. The current version of telehealth, whose forms include telephone calls and video chats, often isn't enough to deliver such nonstop, all-environments communication between medical experts and local doctors especially in underserved areas [4]. The metaverse purports to supplement these engagements by establishing 3D virtual clinics where patients and doctors can interact on a more immersive and individual level [5]. This ability to bridge distance is essential in ensuring that outbred rural populations of patients can be linked to any specialist anywhere on the globe and hence mitigate the risk of pathogen transmission from face-to-face visits. In addition, with the addition of IoT-based wearables, doctors will be able to remotely keep monitoring patients' vital statistics and more actively identify and address any diseases or disorders immediately [6].

As the metaverse is revolutionizing current diagnostic methods, it also plays an important part in the preparation of the psychiatrists of tomorrow. The medical education can have difficulty incorporating practical experience and contextual learning. The metaverse enables students to do this in a low-stakes, safe virtual space where they can exercise their diagnostic reasoning, procedural techniques, and clinical decision-making on virtual patients and with no harm to actual ones. Students can work on critical thinking and hands-on skills needed for effective diagnosis and patient care in the real world with immersive simulations [7,8]

However, while its potential is great, the use of the metaverse for clinical diagnosis encounters major obstacles. Key challenges are the expensive hardware, technical complexity and the potential for a digital divide that could worsen existing health disparities. Most crucially perhaps, there is the privacy and security of sensitive patient information to consider, highlighting an urgent need for solutions such as blockchain which can help maintain data integrity [9,10]. In addition, the ethical and legal problems of AI, including who is accountable for medical mistakes made by computers, as well as so-called algorithmic bias, need to be resolved through sensible regulation. The aim of this study is to explore the metaverse use in clinical diagnose. While this new digital frontier continues to develop, the extent to which this will successfully and fairly integrate with healthcare will derive from a collective push to address these technical, ethical and regulatory challenges and realize its full potential in taking clinical diagnosis into an immersive, precise, ultra-accessible age for all.

MATERIAL AND METHODS

This systematic review was prepared and organized using preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines.

Information sources

The data used was collected from well-known databases which are as follows,
Scopus, Web of Science, PubMed, IEEE, JMIR Publications, Wiley online Library, Wolter Kluwer, and Google scholar.

Search string

In order to meticulously gather information on the topic of interest, various search string was performed on February 2025 and revised on September 2025 which includes the following:

"Metaverse" OR "Virtual Reality" OR "VR" OR" Augmented Reality" "AR" OR "XR" OR "clinical diagnose" OR "medical pedagogy" OR "medical teaching" OR "clinical education assessment" OR "clinical skills" OR "Simulation Training" OR "immersive technology" OR "medical training" OR "clinical education" OR "simulation-based learning" OR “Metaverse use in medical education” OR “Metaverse use in healthcare education”

Inclusion criteria

This systematic review comprised studies that addressed the created or utilized metaverse in clinical diagnosis, clinical education, health education, and clinical training with a medical scenario. Study selection, the articles in English language were included to maintain clarity and consistency of analysis. The review also included studies that investigated the impact of the metaverse on clinical examination. In order to be relevant and up-to-date with the latest developments in Workplace Innovation, only studies from 2021 to 2025 were included.

Exclusion criteria

Studies published in a language other than English were excluded from the review to allow consistent and accurate interpretation of the content. We also excluded studies less than 2 pages because it was felt that they would not provide adequate information for analysis. Also, papers that focused on the use of metaverse in fields other than the primary area of interest (i.e., medical education, nursing and healthcare setting settings) were excluded since we aimed at producing results for a specific field.

Data extraction and synthesis:

Through an extensive electronic database search conducted in eight databases Scopus, Web of Science, PubMed, JMIR Publications, IEE, Wiley online Library, Wolter Kluwer and Google scholar we identified 2635 records. After duplicates were removed 1988 records remained, and underwent title and abstract screening (Figure 1), 1555 of which were further excluded for not meeting the pre-defined inclusion criteria. Then 33 full-text articles were screened for eligibility. Of these, 33 articles were excluded as they did not address the research purpose; while 4 were excluded based on the lack of complete information or for methodological shortcomings. The total number of included studies that met full inclusion criteria and provided data for final qualitative synthesis was 27. Data related to these studies were systematically extracted and synthesized in order to fit the purposes of this review.

Figure 1: PRISMA Guidelines of the studies

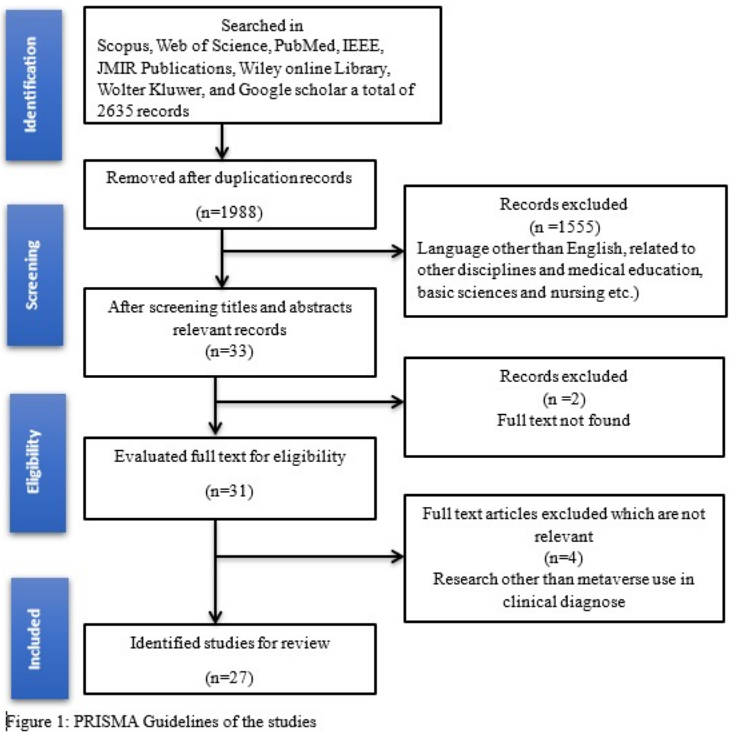

Figure 1: PRISMA Guidelines of the studies

RESULT

Applications of Metaverse, AR, and VR in Clinical Diagnosis

The table 1 highlights how immersive technologies have already entered diverse clinical diagnostic contexts, with most traction in imaging-rich and collaboration-dependent specialties.

Sr#	Author & Year	Clinical	Applications in Clinical Education	Challenges	Conclusion	Study Type
1	Qian Li et al., 2025 [11]	Applied in surgery training, anatomy teaching, communication skills, neurosurgery, ophthalmology, radiology, orthopaedics, and nursing skill development	Immersive technologies boost learning by enhancing skills, confidence, teamwork, and knowledge retention, while offering standardized, hands-on, and engaging training.	Challenges include high costs, technical barriers, and side effects like dizziness and nausea.	Metaverse technology proves effective for medical teaching, offering theoretical support for further research. It has positive potential and provides a theoretical foundation for future research	Systemic review
2	Merve Turan Akdağ, 2025 [12]	Mental health counseling (patient perspective). Patient care and remote medical counseling (dual perspective). Virtual hospitals to improve accessibility for patients with disabilities or in remote areas.	Immersive technologies provide realistic 3D training, enable virtual practice anytime, and visualize complex concepts.	Challenges include data security, privacy, socio-ethical and technical issues, user adaptability, and reduced real-world interaction. Gaps remain in regulations, database coverage, platform choice, and large-scale quantitative research.	Realizing its potential requires strategic approaches, updated regulations, stakeholder collaboration, and a human-centered focus to avoid dehumanization.	Qualitative study
3	Nasim & Garavand, 2025 [13]	Metaverse, AR, and VR aid early diagnosis in multiple specialties, support rehabilitation and complex data analysis, and extend to mental and physical disorders.	Contributes to improving education, training of healthcare professionals, and the realization of medical education. Supports consulting and increasing people's knowledge.	Challenges include unreliable studies, high costs, technical limits, and legal ethical concerns like privacy and unclear regulations. Low adoption, training needs, integration issues, side effects, and social or doctor–patient impacts also persist.	The metaverse shows strong potential for improving complex diagnoses and virtual interactions but faces financial, technical, legal, and acceptance challenges. More research and interdisciplinary collaboration are needed to realize its effectiveness.	Comprehensive survery review study
4	Calabrò and Morone, 2025 [14]	In rehabilitation, the metaverse enables safe, personalized therapy that reduces pain, improves function, and	Not explicitly detailed, but as a perspective on rehabilitation medicine, the applications are primarily clinical for patients, with	Ethical concerns, technological barriers, and clinical efficacy are key challenges. Integration must be approached with caution, guided by	The metaverse represents a transformative opportunity to reimagine rehabilitation medicine, offering innovative solutions	Perspective study

		supports recovery and social reintegration.	implicit educational aspects for therapists and trainees in this field.	robust ethical frameworks and substantial research investment.	for patient engagement, functional recovery, and social reintegration.	
5	Sait and Sarumathy, 2025 [15]	In clinical trials, the metaverse enables investigator–subject interaction, therapy monitoring, consultations, and follow-ups, while integrating wearables, biosensors, and IoT tools for real-time safety tracking and treatment compliance.	Not explicitly mentioned in terms of formal medical education, but clinical trials are a crucial aspect of medical research and contribute to the knowledge base that informs medical practice and training.	Requires rigorous validation of the virtual environment for data collection. Ensuring identity protection of subjects is critical. The application interface must be designed simply to cater to various patient populations.	The metaverse has potential for clinical trials, enabling remote interaction and real-time monitoring. Its successful implementation requires careful validation, user-friendly design, and consideration of associated costs.	Conceptual overview
6	Kulkarni et al., 2024 [16]	Disease prediction in healthcare using digital twin and BLS	Integrating digital twins in predictive models for medical education	Gradient instability, slow training, integration issues in BLS	The DAE-BLS model enhances disease prediction accuracy and adapts rapidly in dynamic healthcare scenarios	Experimental
7	Huang et al., 2024 [17]	Emergency scenarios: spinal injury, humeral fracture, CPR, tracheal intubation, bronchoscopy	Virtual reality-based immersive teaching with panoramic videos and Unity VR applications for emergency skill training	Limited devices (3 VR machines), modest comfort levels (69.23%), lack of tactile feedback, small sample size	Effective in enhancing emergency skills, high student satisfaction, cost-effective, scalable	Review
8	Wang et al., 2024 [18]	The metaverse revolutionizes prevention and treatment through remote care and digital twins for recovery prediction and therapy planning.	AR, VR, and the Metaverse transform medical education with immersive, cost-effective training that enhances skills and readiness for practice.	Technological maturity, data security, user accessibility, and clear regulations are essential for safe and effective use of metaverse platforms in healthcare.	The metaverse offers great potential in healthcare, but overcoming challenges requires continuous innovation and collaboration for real progress.	Comprehensive review
9	Faezeh Ghaempanah et al., 2024 [19]	The metaverse supports patient care by connecting remote patients with specialists, enabling test sharing, maintaining records, and supplementing	The metaverse enhances collaboration, simulation-based training, and remote access, boosting skills, communication, and critical thinking while AR tools simplify	Challenges include unrealistic expectations, ethical concerns, data security, lack of guidelines, resistance to innovation, and imbalance between real and virtual training	The metaverse's impact on medical education, urging its integration as a supplement. Future work should improve usability, affordability, access, engagement, ethics, and clear usage guidelines.	Narrative review

		traditional medicine.	anatomy learning and reduce errors.	highlighting the need to treat the metaverse as a supplement, not a replacement.		
10	Alonso et al., 2024 [20]	Designing a virtual rehabilitation program for chronic low back pain.	Enhanced patient interaction through virtual focus groups.	Initial setup costs, cybersickness, technical glitches, lack of advanced non-verbal communication, privacy concerns, and discomfort with head-mounted displays.	VR focus groups offer immersive, cost-effective solutions; early findings suggest improved patient engagement and satisfaction. Opens avenues for broader use in healthcare and patient interactions.	Prospective
11	Ahuja et al., 2023 [21]	AI-powered digital avatars for patient interaction, virtual therapy for psychiatric conditions	VR/AR tools for anatomy and radiology education, virtual clinical training, and surgical training	Depersonalization of care, VR-induced side effects (nausea, DPDR), cost of implementation, ethical concerns	Metaverse technology has potential to revolutionize medical education and clinical care but requires further exploration and regulation.	Commentary
12	Coşkun & Elmaoğlu et al., 2023[22]	Potential for improving adolescents' access to health-related information and fostering healthy lifestyle beliefs	Enhances e-health literacy through integration into educational programs	Variability in metaverse adoption; need for further evidence on sustained impacts	The metaverse significantly influences adolescents' health perceptions and e-health literacy.	Quantitative
13	Elhenawy et al., 2023 [23]	Health Surveillance, Telemedicine, Virtual Surgical, Fitness & Wellness	Medical Training & Education, Virtual Learning Platforms	Integration with current systems, high costs, access issues, ethical concerns, balancing online and offline activities	The study highlights the potential of Metaverse in healthcare, especially in telemedicine and education, while addressing the need for strategic integration and overcoming barriers such as costs, access, and ethical norms.	Empirical Case Study
14	Hulsenet al., 2023 [24]	Virtual consultations, therapy, drug development, laboratory medicine	Virtual classrooms, medical training, VR/AR-based simulations	Ethical concerns, privacy risks, cost of VR/AR, lack of regulations, social isolation, technical reliability issues	The metaverse can revolutionize healthcare, but requires addressing ethical, technical, and social challenges with dedicated metaverse-specific laws.	Review

15	Kim & Kim et al., 2023 [25]	Digital therapeutics for urological conditions (mobile apps, bladder devices, pelvic floor muscle trainers, smart toilets, mixed reality, telemedicine)	VR-based medical training & mixed reality for surgery	Limited clinical evidence for wearable devices, need for trained medical virtualises, issues with patient compliance and comfort with devices	Digital therapeutics have the potential to improve outcomes, reduce costs, and provide patients more treatment options; further clinical evidence is needed for integration into clinical practice	Review
16	Kim et al., 2023 [26]	Cancer care, self-management, non–face-to-face services	Cancer education, training health professionals	Device discomfort, difficulty in use, need for content improvement	Dr. Meta is a promising metaverse platform for cancer care with potential for future expansion and large-scale use	Pilot study
17	Orr et al., 2023 [27]	Virtual reality treatment for stress and anxiety in the metaverse, including outcome measures such as anxiety, stress, pain, fatigue, and functional ability	Potential use in medical education for virtual treatments and self-management training	Retrospective design, potential biases (selection, recall, response), lack of control group, limited external validity, no non-treatment control group, unmeasured confounders	VR treatment is feasible and safe for managing stress and anxiety, showing significant improvements in clinical outcomes. Further studies are needed	Retrospective analysis
18	Zamanet al., 2023 [28]	Remote consultations, telemedicine, virtual hospitals, healthcare access in underserved communities	Virtual training programs, medical simulations, safe environment for practicing skills	Digital divide, accessibility issues, security concerns for healthcare applications	Metaverse has transformative potential for global healthcare by improving access, providing new channels for care, and enhancing education, but challenges like digital divide and security need to be addressed.	Editorial/Research Topic Review
19	Shao et al., 2023 [29]	Medical diagnosis, treatment, rehabilitation, interaction between medical personnel and patients in digital space	Medical training, education using extended reality (XR), virtual patient interactions	Data volume issues, interaction device limitations, data privacy concerns, high technology cost, balance between reality and virtualization	The medical metaverse is still evolving but has significant potential to transform healthcare and medical research once the technology matures	Review/Conceptual
20	Bhat et al., 2026 [30]	Telemedicine, Virtual Consultations, Augmented Reality in Surgery, Personalized Treatment Plans,	Virtual Simulations, Interactive Surgical Training, 3D Anatomy Dissections, Collaborative Learning	Data Privacy, Technological Interoperability, Ethical Considerations, Regulatory Challenges	The Healthcare Metaverse has vast potential to transform patient care, education, and research, but challenges like data security and	Preprint (Not Peer-Reviewed)

		Rehabilitation, Remote Patient Monitoring			interoperability must be addressed for widespread adoption	
21	Ganapathy et al., 2022 [31]	Telehealth consultations, immersive clinical interactions, digital twins	Augmented learning environments, VR-based simulations	Demonstrating significant healthcare outcome improvements, data privacy, regulatory barriers	Potential to revolutionize patient care and education, requires validation for business models and insurance reimbursement	Review
22	Liu et al., 2022 [32]	PTSD, Anxiety & Fear disorders, Diseases of the Nervous System, Pain Management	VR as a tool for cognitive behavior therapy and rehabilitation	Lack of standard approaches, technical, physical, and investment risks	VR has potential in Health 4.0, improving therapy for mental and physical health, customizable for various conditions	Bibliometric
23	Benrimoh et al., 2022 [33]	Potential to improve tools like VR-assisted therapy, avatar therapy, and teletherapy for mental health care.	Facilitates immersive learning experiences, potentially enhancing understanding through virtual simulations and interactions.	Lack of clarity on the metaverse's evolution, mental health risks similar to social media, and data privacy concerns.	Metaverse may enhance mental health tools and educational approaches but requires careful planning, research, and regulatory mechanisms to mitigate risks.	Commentary
24	Skalidis al., 2022 [34]	Enhancing virtual visits, assisting cardiovascular interventions, improving care via telemedicine, AR, and VR	Reshaping medical education, VR/AR training environments	High costs, infrastructure needs, access disparities, regulatory/legal issues, privacy concerns, loss of physical/non-verbal interaction	The metaverse holds potential to revolutionize cardiovascular medicine and education, requiring innovation to address cost, regulation, and trust challenges.	Review Article
25	Wang et al., 2022 [35]	AI-based medical imaging, virtual comparative scanning, augmented regulatory science, and metaversed medical interventions	Potential use in medical training, virtual patient interactions, and AI-based diagnostic learning	Privacy, security, data disparity, regulatory challenges	The MeTAI metaverse can enhance healthcare quality, accessibility, and cost-effectiveness through AI and virtual technologies	Review/Conceptual
26	Yang et al., 2022 [36]	AI and data science enhance hospital workflow, diagnosis, drug discovery, precision medicine, and patient care	Metaverse can simulate operation theaters, procedures, and healthcare education programs	Explainability of AI, patient-hospital trust issues, lack of AI empathy, data security, and ethical concerns	AI, data science, and metaverse will continue to evolve, offering benefits in hospital management and healthcare delivery	Review

27	Usmani et al., 2021 [37]	Virtual reality (VR), augmented reality (AR), and mixed reality (MR) tools have been used in the treatment of various mental health disorders.	Exploration of the potential role of VR, AR, and MR in transforming mental health treatment, especially in environments like the metaverse.	Increased risk of mental health deterioration due to gaming addiction, unrealistic comparisons, and social media influence. Not everyone can access the required devices, and some groups may be resistant to using VR.	Metaverse technology offers potential for expanding mental health support but presents several risks, including exacerbating mental health issues. However, it can also improve access to care.	Literature review

A recent systematic review by Qian Li et al [11] showed that VR and AR consistently improved diagnostic understanding and skill acquisition across clinical training and assessment, though methodological variation limited generalizability. Wang et al. [35] reported that VR environments enhanced diagnostic imaging interpretation and decision-making accuracy, particularly in radiology, by offering interactive 3D manipulation of CT and MRI scans. Similarly, Yang et al. [36] concluded that AR-assisted visualization improved anatomical localization and surgical planning, underscoring the value of immersive overlays for both education and clinical diagnosis.

In oncology, immersive tumor boards and VR pathology visualization have accelerated shared decision-making and diagnostic consensus [18, 22,35] demonstrated that VR tools improved multidisciplinary communication, while [34] reported that immersive counseling environments enhanced patient comprehension of diagnostic findings. Applications also extend into mental health and rehabilitation diagnostics. VR simulations provide objective measures for anxiety, PTSD, and depression [24,32,33], while immersive rehabilitation platforms support motor-function diagnostics and tracking in neurology and physiotherapy [14, 20]. In emergency medicine, Huang et al. [17] found VR training increased CPR and airway diagnostic accuracy, preparing clinicians for high-stakes diagnostics in real settings.

Interpretation: Current applications confirm that immersive platforms enhance visualization, collaboration, and communication in diagnosis. Their strength lies in contexts where spatial data, patient engagement, and multi-stakeholder decision-making are critical.

Table 1: Summary of selected studies for systematic literature review on metaverse use in clinical diagnose

Applications of Metaverse, AR, and VR in Clinical Diagnosis

The applications table highlights how immersive technologies have already entered diverse clinical diagnostic contexts, with most traction in imaging-rich and collaboration-dependent specialties.

A recent systematic review by Qian Li et al. [11] showed that VR and AR consistently improved diagnostic understanding and skill acquisition across clinical training and assessment, though methodological variation limited generalizability. The authors [14,37] reported that VR environments enhanced diagnostic imaging interpretation and decision-making accuracy, particularly in radiology, by offering interactive 3D manipulation of CT and MRI scans. Similarly, Yang et al. [36] documented that AR-assisted visualization improved anatomical localization and surgical planning, underscoring the value of immersive overlays for both education and clinical diagnosis.

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Interpretation: Current applications confirm that immersive platforms enhance visualization, collaboration, and communication in diagnosis. Their strength lies in contexts where spatial data, patient engagement, and multi-stakeholder decision-making are critical in table 2 and figure 2.

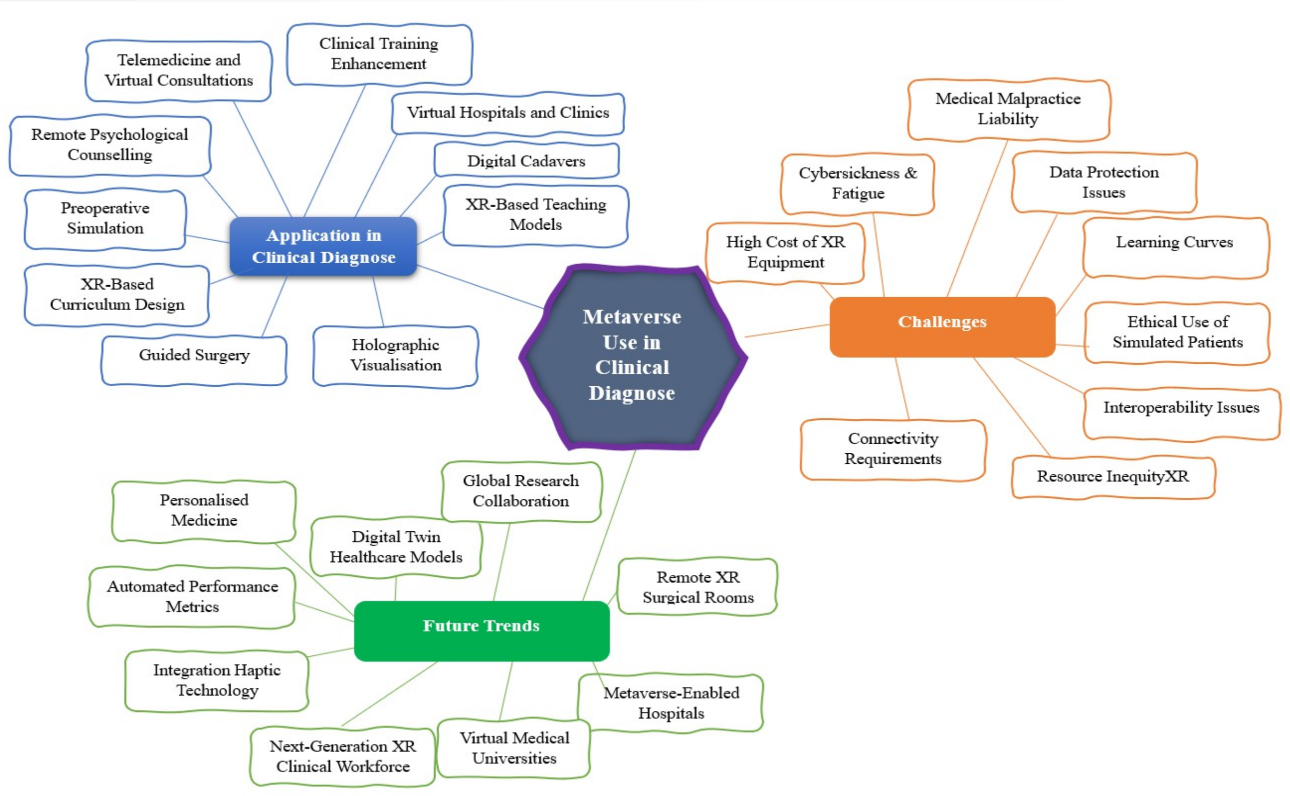

Figure 2: Metaverse use in clinical diagnose

Table 2: Applications of Metaverse, AR, and VR in Clinical Diagnosis

Main Theme	Subthemes	Metaverse / AR / VR / Technology Used in Clinical Diagnosis	References
Surgical & Procedural Training	1. High-fidelity surgical simulation 2. Laparoscopic/robotic skills practice 3. Emergency procedure rehearsal 4. OR teamwork training 5. Crisis management drills 6. Rare-case practice 7. Haptic-feedback-based skills 8. Standardized competency evaluation 9. VR psychomotor metrics 10. Scenario branching & adaptive difficulty	VR surgical simula operating rooms, haptic (overlays on anatomical m	[11, 17, 24,34,37]
Anatomy Education & Spatial Learning	1. 3D interactive anatomy models 2. Layered dissection simulations 3. Cross-sectional imaging correlation 4. Embryology visualization 5. Pathoanatomy overlays 6. Multi-user exploration 7. Self-directed learning 8. Assessment via 3D tasks 9. Annotatable shared scenes 10. Virtual organ manipulation	AR overlays, VR 3D anatomy worlds, interactive volumetric MRI/CT models	[11, 27, 22, 28,29,31, 36]
Diagnostic Imaging & Early Disease Detection	1. 3D/volumetric visualization 2. Multi-modal image fusion 3. AI-assisted lesion detection 4. Radiology education modules 5. Interactive segmentation 6. Depth perception for complex anatomy 7. Tele-radiology support 8. Temporal imaging visualization 9. Remote collaborative diagnosis	VR/AR-based volumetric rendering, AI-integrated imaging, stereoscopic visualization, digital twins for predictive modelling	[12,13,16, 18,22,25-28,35,37]

Telemedicine & Remote Consultation	1. Virtual clinic rooms 2. Remote patient monitoring 3. Multi-disciplinary boards 4. Remote mentoring 5. Shared imaging in virtual space 6. Patient–clinician rapport in VR 7. Data security & privacy management 8. Latency & connection evaluation 9. Remote vitals integration 10. Cross-border consultations	Telepresence avatars, AR-guided remote exams, VR consultation platforms, IoT wearables integrated in metaverse environments	[12, 15,19,27, 29,32,34, 37]
Rehabilitation & Motor Retraining	1. Gait training 2. Upper-limb exercises 3. Balance and vestibular rehab 4. Pain reduction programs 5. Gamified adherence modules 6. Home-based telerehab 7. Biofeedback integration 8. Progress tracking dashboards 9. Neuroplasticity-targeted interventions 10. Virtual therapist guidance	VR/AR rehab platforms, motion capture sensors (Kinect, inertial), biofeedback systems, mixed reality for motor assessment	[14,17,20, 22,25,29, 33,36]
Mental Health Assessment & Therapy	1. VR exposure therapy 2. Social anxiety role-play 3. Depression management 4. Addiction treatment 5. Cognitive remediation 6. Mood/affect sensing 7. Virtual group therapy 8. Stress biofeedback 9. Standardized diagnostic interviews 10. Longitudinal symptom tracking	VR exposure therapy, AR-assisted CBT, sensor-based physiological monitoring, avatar-assisted therapy	[12,19,22, 25,28,31-33,36]
Pain Management & Distraction	1. Acute procedural distraction 2. Chronic pain coping 3. Guided imagery 4. Graded exposure for pain-related fear 5. Patient-tailored immersive environments 6. Pain threshold evaluation 7. Long-term adherence monitoring 8. Rehabilitation adjunct	Immersive VR environments, multisensory distraction modules, biofeedback tracking, AR-enhanced visualization	[14,16,11 8,26,30,3 2,37]
Patient Education & Shared Decision-Making	1. Anatomy/pathology visualization 2. Procedure walkthroughs 3. Risk/benefit simulation 4. Medication mechanism demos 5. Chronic disease self-management 6. Multi-language accessibility 7. Comprehension evaluation 8. Family engagement modules 9. Patient literacy support	AR/VR visualizations, interactive consent modules, 3D modeling of disease and therapy plans	[18,23,28, 32,35]
Clinical Assessment & Screening	1. Virtual standardized exams 2. Motor function tests 3. Cognitive screening 4. Fall-risk evaluation 5. Remote vitals integration 6. Behavioral performance tracking 7. At-home testing protocols 8. Longitudinal monitoring 9. Automated alerting systems 10. Adaptive assessment tools	Motion capture + VR tasks, AR-guided point-of-care scanning, wearable sensors for assessment and remote diagnostics	[13, 17, 23,28,31, 35]
Interprofessional Education & Teamwork	1. Multi-user VR simulations 2. Communication training 3. Role-play for handoffs 4. Leadership skill training 5. Collaborative procedural practice 6. Error disclosure drills 7. Cross-cultural teamwork scenarios 8. Debriefing tools with replay 9. Multi-disciplinary scenario-based assessment	Multi-user VR spaces, AR shared overlays, synchronized haptic feedback for team training, immersive replay analytics	[11,14,16, 19,22,29, 33,36]
Ethics, Privacy & Accessibility	1. Data security & patient privacy 2. Consent for immersive data 3. Equity & digital divide 4. Low-literacy usability 5. Age accessibility 6. Motion-sickness mitigation 7. Regulatory compliance 8. Cultural sensitivity in avatars 9. Data governance & storage 10. Interoperability standards	Secure metaverse platforms, encrypted data streams, accessibility toolkits, privacy-preserving cloud processing	[12,25,29, 31,32,35, 37]
Evaluation, Outcomes & Implementation Science	1. Clinical effectiveness trials 2. Cost-effectiveness analyses 3. Implementation barriers 4. Fidelity & scalability 5. User adoption metrics 6. Regulatory pathway adherence 7. Real-world evidence collection 8. Standardized outcome measures 9. Long-term follow-up 10. Reporting guidelines	VR/AR analytics platforms, EHR integration for outcome tracking, dashboards for diagnostic and training endpoints	[11,14,16, 17,21,24, 25,29,31-34,36]

Disease Prediction & AI Integration	1. Predictive modeling 2. Digital twin integration 3. Early disease detection 4. Risk stratification 5. Diagnostic decision support 6. AI-assisted imaging 7. Remote patient monitoring 8. Personalized therapy planning	Digital twins, BLS-based predictive models, AI-enhanced AR/VR diagnostic simulations, real-time monitoring via metaverse dashboards	[13, 16,20,22, 25,28,34]

Challenges of Using Metaverse, AR, and VR in Clinical Diagnosis

Despite promising applications, adoption remains uneven and fragmented, largely due to structural, methodological, and ethical constraints.

From a technical perspective, device limitations, latency, and interoperability are recurring obstacles. Shao et al. [29] noted that hardware limitations reduce immersion quality, while [36] emphasized interoperability gaps between AR/VR systems and clinical imaging standards. Huang et al. [17] further identified cybersickness and discomfort as barriers to sustained use.

Methodological weaknesses were a major theme in Qian Li et al. [11] who found that most studies relied on small, convenience samples with inconsistent diagnostic indicators. This restricts generalizability across patient populations and clinical specialties. Geographical skew studies clustered in Europe and the United States further limits insights into applicability in low- and middle-income countries (LMICs).

Ethical and legal uncertainties compound these issues. The researchers [17,21,34,] emphasized the unresolved challenges of data security, cross-border regulation, and informed consent in virtual diagnostic environments. Sait & Sarumathy [15] highlighted specific gaps in privacy protections for patient avatars and immersive identity. User adaptability remains inconsistent, with [19,26] noting variable clinician comfort, while [12] warned of depersonalization risks in digital clinical interactions. Interpretation: The diagnostic value of immersive technologies is evident, but their reliability, scalability, and ethical integrity remain unsettled. Addressing methodological rigor, regulatory clarity, and equity of access is essential for wider adoption (figure 2).

Table 3: Solutions for Advancing Clinical Diagnosis through Metaverse, AR, and VR

Main Theme (Solution Area)	Subthemes	References
AI-Driven Diagnostic Precision	1. AI-based VR pathology analysis 2. Deep learning for image reconstruction 3. Automated anomaly detection in scans 4. VR-enabled predictive analytics 5. Personalized diagnostic simulations 6. AI co-pilots for radiologists 7. NLP-driven diagnostic reporting 8. Multimodal AI fusion (CT, MRI, VR) 9. Adaptive learning diagnostic algorithms	[11,17,22, 34]
Next-Gen Imaging & Visualization	1. 3D organ reconstruction in VR 2. AR overlay for tumor margins 3. Metaverse-based comparative imaging 4. Holographic diagnostics 5. Real-time VR biopsy guidance 6. Micro-detail magnification tools 7. Cross-modality immersive imaging 8. Virtual histopathology 9. Digital twin organs for diagnosis	[13, 19,22,28,31, 36]
Remote & Collaborative Diagnosis	1. Multi-user VR diagnostic rooms 2. AR telepathology consultations 3. Real-time global case reviews 4. VR supported tumor boards 5. Shared 3D imaging repositories 6. Virtual multidisciplinary clinics 7. Remote radiology teaching in VR 8. AR-based surgery diagnosis bridges 9. Cross-border virtual health consortia	[16,18,24, 28,30, 32,25]
Patient-Centered Diagnostic Engagement	1. VR walkthrough of patient scans 2. AR apps explaining conditions 3. Immersive diagnostic counseling 4. Gamified patient education 5. Interactive 3D treatment planning 6. VR anxiety reduction during tests 7. Customized avatars for communication 8. Inclusive visualizations for disabled patients 9. Patient co-design of VR diagnostic tools	[14,19,22, 25,29,37]
Integration with Wearables & IoT	1. Smartwatches feeding VR diagnostics 2. Wearable ECG–VR sync 3. Continuous glucose monitoring in AR 4. VR-enhanced telecardiology 5. IoT-linked VR dashboards 6. Predictive alerts from wearables in VR 7. Smart sensors for immersive monitoring 8. VR-enabled portable ultrasound 9. Cross-device interoperability	[11, 18,19,27,29,30, 32,37]
Simulation for Complex Case	1. Digital twin patient diagnostics 2. VR trial runs before invasive tests 3. Simulated rare disease diagnosis 4. Predictive "what if" diagnostic	[13, 36, 37]

Testing	models 5. AR rehearsal for biopsy planning 6. Simulation libraries for medical education 7. Dynamic case replays in VR 8. Safe failure environments 9. Standardized VR case-based assessments	
Precision Medicine & Personalization	1. VR-based genetic diagnostics 2. AR overlays of personalized risk factors 3. Individualized treatment visualizations 4. Immersive pharmacogenomics simulations 5. Digital twin genomics integration 6. AI-driven personalized disease trajectory mapping 7. Patient-specific VR models for surgery planning 8. Tailored rehab diagnostic tracking 9. Lifestyle-linked VR health predictions	[14,17,23,26,30,33,35]
Global Health Equity Solutions	1. Low-cost diagnostic VR kits 2. Solar-powered VR clinics 3. Multilingual immersive diagnostics 4. Offline VR diagnostic modules 5. Open-access AR health apps 6. Decentralized diagnostic learning hubs 7. VR-based training for rural providers 8. Cross-cultural diagnostic avatars 9. WHO-led global VR diagnostic libraries	[13,16,19,22,26,31,33,37]
Sustainability & Green Innovation	1. Energy-efficient VR devices 2. Eco-friendly headset materials 3. Cloud-based diagnostics reducing travel 4. Reusable AR diagnostic components 5. Carbon-neutral metaverse hospitals 6. Circular economy in VR hardware 7. Low-energy immersive imaging software 8. VR replacing resource-heavy physical labs 9. Green certification for diagnostic tools	[13,17,24,28,31,33]

The solutions table identifies practical levers to transform challenges into opportunities, aligning closely with evidence-based recommendations.

Technical strategies include cloud/edge computing, 5G/6G infrastructure, and open standards to mitigate latency and ensure interoperability [17, 22,29, 36]. Integration with existing clinical imaging systems (e.g., DICOM-in-VR) will be crucial for mainstream adoption.

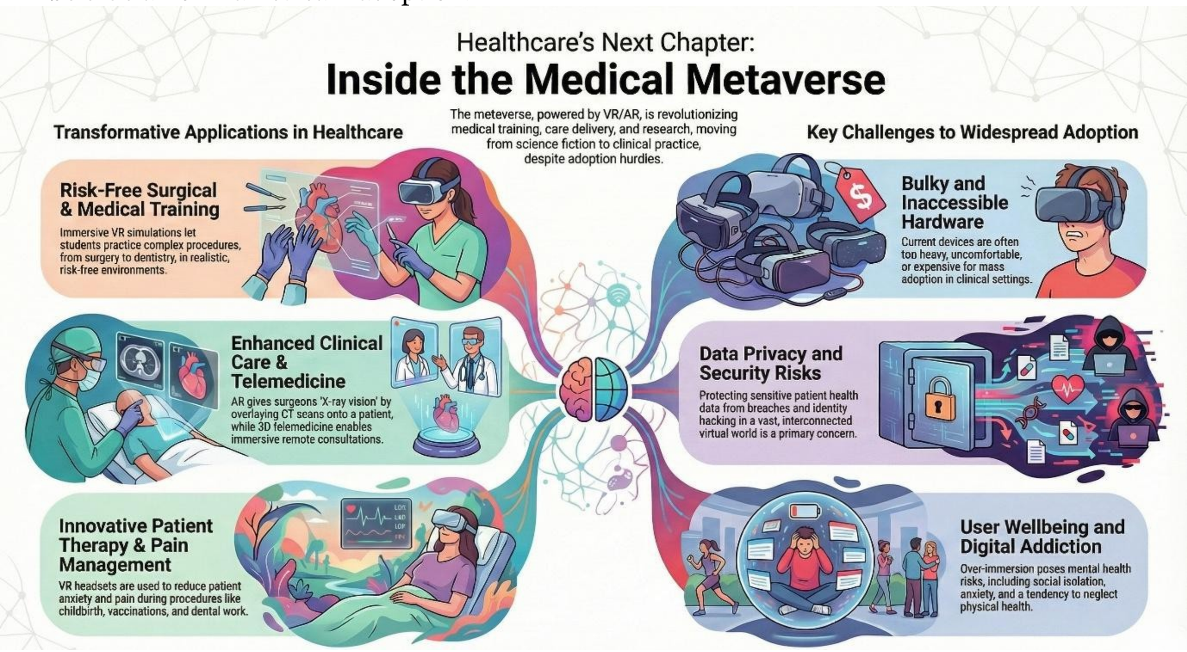

Figure 3: Future of clinical & health care

Trust and safety are central. Sait & Sarumathy [15] emphasized the importance of secure encryption protocols and patient-consent workflows within immersive platforms. Hulsen et al. [24] proposed cross-border digital ethics standards, while [12] advocated for identity and data protection safeguards to ensure patient confidence in VR-based diagnosis.

Evidence-building is another critical solution. Qian Li et al. [11, 13], and Wang et al. [35] all highlighted the need for larger, multicentred trials with standardized diagnostic benchmarks. Explainable AI modules embedded in VR/AR will help address transparency concerns while also strengthening diagnostic validity. For equitable access, Zaman et al. [28] and [14] suggested tiered pricing models, shared device pools, and public–private partnerships to reduce costs.

Finally, human-centered deployment addresses clinician adaptability challenges. Structured onboarding, ergonomic design, and cybersickness mitigation are recommended to improve acceptance [11,22,29,33].

The pathway forward relies on technical robustness, ethical safeguards, rigorous evidence, equitable access, and user-centered design. These solutions map directly to the barriers highlighted across studies. The opportunities table demonstrates how immersive technologies are poised to reshape diagnostics by moving towards precision, prediction, and accessibility. AI and Digital Twins are among the most transformative opportunities. Kulkarni et al. [16] emphasized their potential in generating patient-specific simulations, [13] and Wang et al. (2024; 2022) reported applications in predictive modeling and oncology diagnostics. These advances support a shift from reactive diagnosis to predictive and preventive diagnostics (figure 3).

Advanced visualization opportunities lie in rare and complex diseases. VR and AR can provide holographic reconstructions of cardiac anomalies and metabolic disorders, improving interpretive accuracy where traditional imaging struggles [25,29,36].

Global collaboration is another future direction. Zaman et al. [28] demonstrated VR tele-diagnostic boards and AR-enabled pathology reviews that expand expertise to underserved and rural areas. Patient engagement represents a growing opportunity. VR counseling, immersive lab result explanations, and patient avatars have been shown to reduce diagnostic anxiety and improve health literacy [14,19,22,33,36].

Finally, governance and policy developments will define the scalability of immersive diagnostics. Regulatory frameworks from [22,25,32,26] stress the need for WHO, FDA, and EMA guidance to ensure legal and ethical compliance. The future lies in AI-integrated immersive diagnostics, rare disease visualization, global tele-collaboration, patient-centered engagement, and robust governance. These directions will redefine diagnostics as personalized, predictive, preventive, and globally inclusive (figure 3).

DISCUSSION

The integration of the Metaverse, augmented reality (AR), and virtual reality (VR) into clinical diagnostics is increasingly recognized as a transformative force in modern healthcare. As the preceding tables and framework illustrate, these technologies hold considerable promise for enhancing diagnostic precision, clinician collaboration, and patient engagement. However, their adoption is not without obstacles. Persistent methodological, technical, ethical, and systemic challenges continue to shape the trajectory of immersive technologies in clinical contexts. The following discussion synthesizes findings across applications, challenges, solutions, and opportunities, situating them within the current body of research and identifying implications for future development.

Expanding the Boundaries of Diagnostics

The evidence highlights that immersive technologies have moved beyond theoretical potential and are actively being applied in clinical diagnostics. In radiology and oncology, VR and AR systems enable clinicians to visualize tumors, lesions, and complex anatomical structures in three dimensions, facilitating collaborative decision-making and improving diagnostic accuracy. For instance, [11,38] found that immersive visualization significantly enhanced clinicians' ability to interpret complex imaging data, especially in cases requiring multi-disciplinary input. Similarly, [13] demonstrated the utility of VR tumour boards in oncology, where spatially accurate 3D reconstructions promoted deeper discussions among specialists and yielded more accurate treatment planning. These findings highlight how immersive environments can act as a bridge between traditional imaging modalities and real-time diagnostic collaboration.

Beyond imaging, immersive technologies also show potential in rehabilitation and neurology diagnostics. VR systems have been deployed to monitor motor function recovery in stroke patients, providing clinicians with accurate and dynamic metrics of patient progress. Calabrò and Morone [14] reported that VR-based rehabilitation tools not only improved patient engagement but also allowed clinicians to make earlier and more accurate assessments of recovery trajectories. In neurology, [24,39] found that VR-based pain assessment environments offered clinicians greater insights into chronic pain patterns, improving both diagnosis and patient-provider communication.

Applications in mental health diagnostics represent another significant area of expansion. VR scenarios provide immersive, controlled environments that allow clinicians to assess behavioral and psychological responses more objectively. Studies by [40,41] confirmed that VR-based diagnostic scenarios improved the assessment of conditions such as anxiety, depression, and phobias, while reducing reliance on self-reported measures. These innovations illustrate how immersive tools may address long-standing gaps in mental health diagnostics, where subjectivity has often constrained accuracy in figure 2.

In emergency and critical care, immersive training tools have been linked to improvements in diagnostic speed and accuracy under high-pressure conditions. Huang et al. [17] reported that clinicians trained through VR-based CPR simulations demonstrated faster diagnostic recognition of cardiac arrest and airway blockages compared to those trained through conventional methods. This dual role improving both training and real-world diagnostic practice reinforces the value of immersive technologies in time-sensitive clinical environments. Collectively, these findings underscore that immersive applications are not confined to niche uses but are expanding across a spectrum of clinical specialties, offering practical value in diagnostics that demand precision, speed, and collaboration [41,42].

Barriers to Widespread Adoption

Despite promising applications, numerous challenges constrain the full adoption of immersive diagnostic technologies. Methodological limitations remain particularly pronounced. Many studies rely on small sample sizes, focus disproportionately on populations in North America and Europe, and apply inconsistent diagnostic benchmarks, limiting the generalizability of findings [11, 17,19,32]. This lack of methodological rigor makes it difficult to compare outcomes across studies and undermines the establishment of standardized best practices. The geographic skew also highlights a missed opportunity to test immersive technologies in low- and middle-income countries (LMICs), where healthcare systems could potentially benefit most from cost-effective diagnostic innovations [44, 47].

Technical limitations further constrain adoption. Hardware issues such as poor ergonomics, heavy headsets, and cybersickness reduce usability in clinical settings [17,24]. Latency and bandwidth limitations undermine real-time immersion, particularly in tele-diagnostic contexts [36]. In addition, the lack of interoperability between immersive platforms and established clinical imaging systems, such as DICOM, creates workflow disruptions and reduces clinician trust in the accuracy of diagnostic results [25]. Without seamless integration into existing systems, immersive technologies risk being perceived as experimental add-ons rather than essential diagnostic tools in figure 2.

Ethical and legal challenges pose an equally formidable barrier. Concerns regarding data privacy, security, and informed consent are pervasive in the literature. Hulsen et al. [24] warned that immersive technologies create new vulnerabilities for patient data, particularly when avatars or digital twins are employed. Sait and Sarumathy [15] emphasized the challenges of protecting patient identity in virtual environments, where the use of realistic avatars may blur the line between representation and disclosure. Furthermore, the absence of clear global regulations exacerbates uncertainty around accountability and liability in cases of diagnostic error [31].

Finally, socio-economic challenges threaten to reinforce global inequities in healthcare. The high costs of immersive systems, combined with limited access to advanced infrastructure such as high-speed internet and cloud computing in LMICs, may exclude vulnerable populations from the benefits of these technologies [28]. Merve Turan Akdağ [12] further raised concerns that overreliance on immersive diagnostics could depersonalize care, reducing human interaction and potentially undermining patient trust. These barriers collectively underscore the need for comprehensive strategies that address not only technical and methodological shortcomings but also systemic and ethical considerations.

Roadmaps for Overcoming Barriers

Several studies propose targeted solutions to mitigate these challenges. On the technical front, the integration of 5G/6G infrastructure, cloud computing, and open standards is repeatedly identified as critical for reducing latency and enhancing interoperability [36,42]. Standardization with DICOM protocols and integration into electronic health records could streamline immersive diagnostics into routine workflows, addressing clinician concerns about accuracy and usability.

Ethical and regulatory solutions emphasize the need for robust frameworks tailored to immersive environments. Sait and Sarumathy [15] proposed advanced encryption and identity-protection mechanisms to secure patient avatars, while [24,31,36] argued for the development of international regulatory guidelines that establish clear standards for data ownership, liability, and patient rights. Privacy-by-design approaches, combined with explicit informed consent protocols, may be essential for maintaining patient trust in immersive diagnostics.

Methodological solutions focus on strengthening the evidence base. The researchers [13, 29, 29] recommended large-scale, multi-center trials using standardized diagnostic benchmarks to improve reliability and comparability. Incorporating explainable AI into immersive systems may also enhance clinician confidence by making diagnostic outputs more transparent and interpretable.

Equity-oriented solutions address affordability and access. Zaman et al. [28] proposed tiered pricing models, shared resource pools, and public–private partnerships to expand availability in LMICs. The

[31] emphasized the importance of insurance reimbursement and government policy support to ensure sustainability and reduce financial barriers.

Finally, user-centered design solutions aim to improve adoption by clinicians and patients alike. Alonso et al. [20, 27,31] emphasized ergonomics, ease of use, and training programs as critical to reducing resistance. Addressing cybersickness, creating lightweight hardware, and embedding immersive tools into existing clinical workflows will likely improve both clinician satisfaction and diagnostic reliability. These solutions, taken together, offer a pragmatic roadmap for scaling immersive diagnostics in real-world contexts.

Opportunities and Future Directions

Despite challenges, the opportunities presented by immersive technologies in clinical diagnosis are substantial. One of the most promising frontiers is the integration of artificial intelligence (AI) and digital twins. Kulkarni et al [16] demonstrated that AI-enhanced digital twins can simulate patient-specific disease progression, provide predictive diagnostic insights and enable more proactive care. Similar findings by [13,24,36] confirm that predictive modelling within immersive environments represents a paradigm shift from reactive to preventive healthcare.

Another opportunity lies in rare and complex diseases, where immersive visualizations can enhance diagnostic accuracy. Yang et al [36] reported improved diagnosis of congenital cardiac anomalies through VR reconstructions, while highlighted similar benefits in metabolic disorders. These applications extend the role of immersive technologies into domains where conventional diagnostic tools often fall short figure 3.

Global collaboration also represents a transformative opportunity. Virtual tumor boards, immersive tele-diagnostics, and remote specialist consultations enable healthcare providers in LMICs to access expertise otherwise unavailable locally. The researchers [28,33] emphasized the potential for immersive diagnostics to reduce global disparities in healthcare access, while [48] highlighted their utility in transnational clinical research (figure 3). Patient engagement is another area of potential growth. Immersive tools not only assist clinicians but also empower patients by visualizing diagnostic results, enhancing comprehension, and reducing anxiety. Calabrò and Morone [14, 19,33,45] found that patients using VR-based counselling tools demonstrated greater understanding of their conditions and treatment pathways. Such applications align with broader shifts toward patient-centered care and health literacy [48-50].

Finally, regulatory development presents both a challenge and an opportunity. Studies by [17,24,31,37]stress the importance of global governance structures that adapt to the unique features of immersive technologies. Organizations such as WHO, FDA, and EMA are positioned to play pivotal roles in setting standards that ensure safety, equity, and scalability. These opportunities collectively point toward a future where immersive diagnostics contribute to a healthcare system that is more personalized, predictive, preventive, and equitable.

Conclusion

The integration of Metaverse, AR, and VR technologies into clinical diagnostics holds significant potential to reshape modern healthcare. Current applications in radiology, oncology, neurology, rehabilitation, and mental health illustrate the value of immersive tools in improving accuracy, collaboration, and patient engagement. Yet, methodological, technical, ethical, and socio-economic challenges remain formidable barriers to widespread adoption. Solutions proposed in the literature from advanced infrastructure and regulatory safeguards to equitable pricing and user-centered design offer a viable roadmap forward. The greatest opportunities lie in AI-enhanced diagnostics, rare disease visualization, global collaboration, patient engagement, and regulatory alignment.

If effectively implemented, immersive technologies will not only augment existing diagnostic practices but also enable a healthcare system that is more innovative, equitable, predictive, and patient-centered. The journey toward this future requires interdisciplinary collaboration among researchers, clinicians, policymakers, and technology developers, ensuring that the benefits of immersive diagnostics are realized globally and ethically.

Limitations of the Study

This systematic review has several limitations. The included studies showed high heterogeneity in design, sample size, and outcome measures, making comparisons difficult and limiting the possibility of meta-analysis. Most of the evidence came from high-income countries, with little research from low- and middle-income regions, which restricts the global generalizability of findings. As the Metaverse, AR, and VR are rapidly evolving, some of the reviewed studies may already be outdated, and many suffered from methodological weaknesses such as small samples and lack of standardized diagnostic benchmarks. In addition, most studies examined short-term outcomes like diagnostic accuracy or user satisfaction, with limited attention to long-term effectiveness, cost, or sustainability. The review also relied mainly on peer-reviewed English-language publications, which may have introduced both publication and language bias, excluding relevant non-English and unpublished research. Finally, patient-centered outcomes such as trust, accessibility, and consent were rarely explored, leaving an important gap in understanding the real-world impact of immersive diagnostics.

Implications of the Study

The findings of this systematic review have important implications for healthcare practice, policy, and research. For clinical practice, immersive technologies such as the Metaverse, AR, and VR can improve diagnostic accuracy, enhance collaboration, and support patient-centered care, but clinicians need structured training and user-friendly systems for effective adoption. For policymakers, clear regulatory frameworks, ethical guidelines, and reimbursement models are essential to address privacy, safety, and equity concerns, particularly in low- and middle-income countries where access is limited. For research, there is an urgent need for large-scale, multicenter trials with standardized diagnostic benchmarks, long-term outcome assessments, and inclusion of patient perspectives to build stronger evidence. Finally, technology developers must prioritize interoperability, affordability, and usability to ensure immersive diagnostic tools can be sustainably integrated into diverse healthcare systems.

Future Research Directions

Future research should focus on conducting large-scale, multicenter, and methodologically rigorous studies to strengthen the evidence on the use of Metaverse, AR, and VR in clinical diagnosis. There is a need to move beyond short-term outcomes and evaluate long-term effectiveness, cost-efficiency, patient safety, and sustainability in real-world healthcare settings. Studies should also include diverse populations, particularly from low- and middle-income countries, to improve global relevance and equity. Integration of immersive technologies with artificial intelligence and digital twins warrants further investigation for advancing predictive and personalized diagnostics. Moreover, patient-centered research exploring trust, consent, accessibility, and user experiences is essential for ensuring acceptance and ethical application. Finally, interdisciplinary and policy-oriented research is required to develop clear regulatory frameworks, data security standards, and cost-reduction strategies that support equitable adoption across healthcare systems.

Research Gaps

Despite growing interest in immersive technologies for clinical diagnosis, several research gaps remain. Current evidence is limited by small sample sizes, short follow-up periods, and inconsistent study designs, which restrict the strength and comparability of findings. Most studies are concentrated in high-income countries, leaving limited insights into applicability in low- and middle-income healthcare systems. There is also a lack of standardized diagnostic benchmarks and long-term evaluations of cost-effectiveness, clinical accuracy, and patient safety. Importantly, patient-centered outcomes such as trust, consent, accessibility, and emotional responses remain underexplored. Furthermore, limited research addresses data security, interoperability, and regulatory frameworks, which are critical for clinical adoption. These gaps highlight the urgent need for robust, inclusive, and interdisciplinary studies to guide safe, effective, and equitable integration of Metaverse, AR, and VR technologies into diagnostic practice.

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