Journal of Clinical Orthopaedics and Trauma 48 (2024) 102340

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

journal homepage: www.elsevier.com/locate/jcot

A review of Smart future of healthcare in the digital age to improve Quality of orthopaedic patient care in metaverse called: The Healthverse!!

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1. Introduction

In the medical realm, the metaverse signifies a convergence of Augmented Reality (AR) and Virtual Reality (VR), akin to a medical Internet of Things.[1] As the new age metaverse technology has taken center stage, people tend to confuse it with virtual reality (VR). According to broader definitions, the metaverse represents a futuristic virtual world in 3D. Virtual reality is actually a network of interconnected virtual worlds that can be managed independently. Metaverses, therefore, consist of a multitude of digital universes rather than a single virtual world. Using digital avatars, users could interact with digital content. VR is a cornerstone of the Metaverse platform (Fig. 1). This dynamic fusion incorporates artificial intelligence, virtual and augmented reality, Web 3.0, intelligent clouds, edge computing, quantum computing, and robotics. The metaverse offers new directions in healthcare by combining artificial intelligence, virtual reality, augmented reality, Web 3.0, intelligent clouds, edge computing, quantum computing, and robotics. Digital twins and precision medicine will emerge as we better map and understand individual genetics.[2] Predictions suggest that 25% of people will engage with the metaverse by 2026, using it for work, shopping, social media, entertainment, and education.[3] The Metaverse also introduce a virtual economy centred on digital currencies and non-fungible tokens (NFT) particularly relevant in the healthcare, where NFT can represent patient health records, rewards and digital twins associated with treatment.[4–6] (see Table 1).

In the era of telemedicine, VR is becoming increasingly essential for training clinicians and experts. Its applications range from conducting clinical trials to enhancing patient experiences, promising transformative impacts on healthcare delivery.[7] Metaverse technologies facilitate diverse applications, including cognitive therapy, support groups, psychological evaluations, rehabilitation, and physical therapy with haptic sensors.[8–10] Surgical procedures are witnessing a surge in robotic utilization, while augmented reality is now integral in complex processes.[11] Radiology imaging has the potential to benefit from the metaverse immersive visual capabilities, which will provide new opportunities for the field.[12–14]

2. Key areas where metaverse will be an enabling technology

2.1. Telemedicine and remote medicine

Telemedicine, the provision of remote medical services, has experienced a significant uptick, with 95% of healthcare institutions now offering remote treatment compared to 43% in 2020.[15,16] This shift has been driven by the efficiency of diagnosing minor conditions through telephone or video consultations, making it faster and more convenient than physical appointments. Metaverse platforms and applications need to be able to provide an immersive experience. Metaverse platforms play a crucial role by delivering an immersive experience, particularly through VR headsets, creating a sense of presence unmatched by traditional online channels. This allows patients to virtually meet clinicians worldwide, facilitating scans and tests at local facilities, with results easily shared with specialists globally. In regions with limited access to medical professionals, such as remote areas in India, this approach proves especially beneficial. Patients can also personalize their virtual environments to enhance their healthcare experience.[17,18] When we look at Orthopedics, one of the key areas may be Trauma care in golden hour. It is known that first 60 min following a traumatic injury is crucial and is often referred to as the Golden hour. Prompt and timely attention by trained healthcare professional increases the rate of positive outcome. However, this may not always be possible and it is here a meatverse may enable remote assistance where first responders equipped with AR glass can connect with trauma specialists, surgeons and other expert to provide guidance and support. Enabling a seamless flow

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https://doi.org/10.1016/j.jcot.2024.102340
Received 30 October 2023; Received in revised form 31 December 2023; Accepted 10 January 2024
Available online 11 January 2024

of information and technical know-how is surely going to lead to quicker and more accurate assessments and intervention.

2.2. Precision medicine and digital twins

Precision Medicine, facilitated by digital twins, creates virtual representations of individuals using real-world data in the metaverse. These digital twins, essentially virtual replicas of patients, are envisioned to act as personalized "test dummies." They hold the potential to predict post-surgery recovery rates and individual responses to specific drugs. Achieving this involves advancing our understanding of genetic makeup, allowing for the creation of digital twins that can age by ten years, providing insights based on intervention outcomes.[19] This innovative approach holds promise for tailoring medical interventions to individual characteristics and enhancing treatment efficacy.

2.3. Blockchain technology

Blockchain, commonly associated with cryptocurrencies like Bitcoin, is a distributed and encrypted database that ensures secure data storage and transfer, with alterations possible only by the data owner. Integral to the metaverse concept, blockchain supports decentralized and democratically governed communities, smart contracts, and records digital ownership of environments and objects.[20,21] In healthcare, blockchain plays a vital role in managing and securing health data. Traditional data sharing is often inefficient and opaque, especially with health records stored on vulnerable centralized servers. Blockchain offers a sensible solution, allowing individuals to own their records securely (Fig. 2). This ensures efficient access for clinicians globally while minimizing the risk of hacking, providing transparent and secure healthcare data management.[22–24]

2.4. Education and training in metaverse

In healthcare education, the metaverse, powered by extended reality (XR) technology, is revolutionizing training across various medical disciplines. This includes surgical training, medical test visualizations, treatment methods, and the development of new medicines. The widespread adoption of XR technology is driven by its user-friendly nature and convenience. In Trauma care, one of the crucial yet a potential weak link is the adequacy of training of the first responders. It is here that meta verse and other immersive technologies like Virtual reality (VR) and augmented reality (AR) technologies could be used to enhance medical training for first responders, allowing them to simulate various trauma scenarios and practice critical interventions. Not only will this help them improve their skills and decision-making abilities, It will also ensure that there is an effective response in real-life situations which could happen in diverse settings and environment. It could also be a useful tool during Pandemics like COVID where the access to healthcare got severely Limited.[25]

Table 1
Table 1. Metaverse facilitating Personalised and Precision Medicine in Orthopedics.

1	Data Integration and Analysis
2	Simulation and modelling
3	Patient Engagement
4	Creating collaborative healthcare Spaces
5	Telemedicine and remote patient Monitoring
6	Creating Personalized education and training opportunities
7	Behavioural feedback and analysis loop.

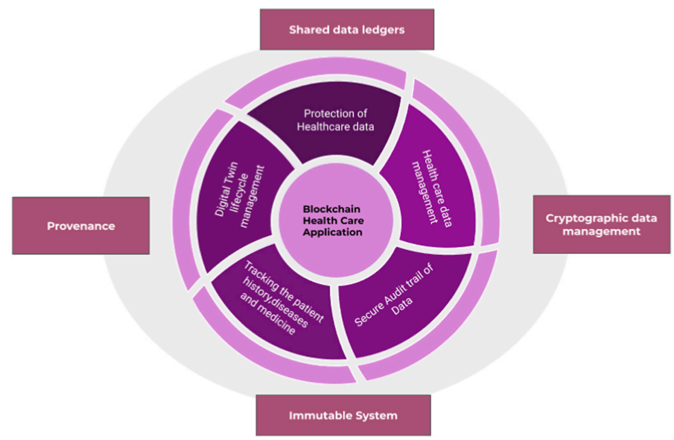

Fig. 2. Blockchain and its Healthcare applications.

2.5. Metaverse benefits in healthcare

- Digital twin technology, used in testing dummies, provides valuable insights into patient responses, surgery outcomes, and potential issues with medical products.
- Medical students benefit from intensive surgical instruction in simulated settings at a fraction of the cost of traditional cadaver-based training.
- Personalized content, recorded using XR, is accessible at the user's convenience, with live-streamed lectures enabling real-time communication with instructors.

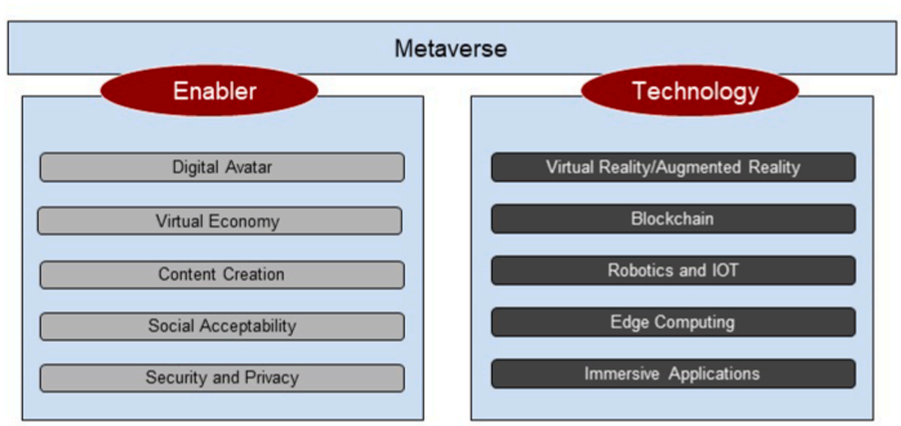

Fig. 1. Pillars of metaverse.

- Virtual reality (VR) facilitates cost-effective simulation of practical surgical procedures, enhancing understanding without real-world risks
- XR revolutionises invasive surgeries by enabling surgeons to record themselves performing medical procedures. By superimposing AR and VR-based models on the patient, surgeons can visualise the patient's anatomy better and plan surgery.
- The metaverse will provide essential clinical data to assist decision-making and reduce cognitive load.
- Despite privacy and data gaps, the clinician is prepared to utilise technological advances to improve patient care and medical training
- Combining with capabilities of AI and immersive experience of meta verse, a robust program that is affordable, accessible, personalized and efficient can be created.[26]

2.6. Convergence and integration

In the future, healthcare professionals can provide more integrated treatment packages due to the convergence of these core technologies within online environments.[27,28] In the metaverse, monitoring patient activity will facilitate tracking factors such as compliance and the diagnosis and treatment of diseases. The symptoms may appear solely physical, but you should also consider the mental effects if they do not improve. Mental health or Depression may prevent the patient from completing their rehabilitative exercises; therefore, the physical injury will not heal.[29] Providing treatment through a coordinated approach through virtual environments, in conjunction with a new method of facilitating data transfer, is believed to result in better treatment outcomes.[30]

2.7. Virtual hospitals and immersive environments

The emergence of virtual hospitals and immersive environments is reshaping the healthcare landscape. Accessed through virtual reality (VR) headsets, these environments offer initial services such as counselling and physiotherapy.[31] In this virtual space, patients receive enhanced feedback on their progress, enabling a more comprehensive understanding of subtle improvements. For instance, a patient with a shoulder joint problem may not physically feel a 3% improvement in range of motion, but the results can be visually reported. As patients advance, personalized plans can be provided, outlining the trajectory towards returning to normal within a specific timeframe, significantly impacting motivation and compliance.[30]

There's a remarkable opportunity in healthcare to harness the potential within the space between the real and entirely virtual worlds. The metaverse, utilized in medical education at various levels, proves invaluable for medical students, residents, and attending physicians. Leveraging the metaverse in digital surgery, medical images are automatically imported, visualized, and segmented to create accurate three-dimensional representations.[32] Segmented 3D models facilitate anatomical measurements, diagnostics, and treatment planning (Fig. 3). Through the VR metaverse, clinicians can simulate unique patient pathologies and manipulate images more effectively, utilizing immersive capabilities for enhanced medical education and practice.[33]

2.8. 'Keys to the metaverse': avatars

The word avatar derives from the Sanskrit word for the descent, which refers to deities taking on human form and descending to Earth. In the Metaverse, avatars play a significant role in shaping user psychology and actions. People can create their avatars and port them to dozens of virtual space platforms, allowing one avatar to serve as master. Avatars can be customised in height, weight, skin tone, hair colour, and clothing. Importantly, avatars are not confined to a single metaverse; they can seamlessly move between instances facilitated by blockchain technology. This enables easy transferability of avatars from one blockchain-based NFT system to another.

2.9. Types of avatars

Software systems can create Avatars in virtual environments in both 3D and 2D. Avatars created in real-time 3D are becoming standard in VR solutions due to their ability to emulate real-world movements with the aid of sensors (Fig. 4).

There are two primary forms of avatars:

VR avatars: Besides having an upper torso and arms, they are equipped with face-tracking capabilities that can be used for collaborative work and for expressing emotion. Platforms like Meta's Horizon Worlds, Microsoft's AltspaceVR, and Spatial employ these technologies.

Full-body avatars: Developed with the rise of virtual reality, full-body avatars enable seamless movement in virtual environments. As a result of sensors, VR hardware can replicate and recreate the entire body's movements. As a result, the user has greater mobility inside virtual spaces to interact with digital assets.

2.10. "LOVE" framework for improving quality of life

Surgical teams can virtually learn new procedures without being

Fig. 3. Illustration of virtual hospital in metaverse.

Fig. 4. Avatar performing surgery in Metaverse.

present in the operating room, with over eight healthcare executives anticipating positive impacts from the metaverse, as per Accenture's Digital Health Technology Vision 2022 report. Technology development allows patients with terminal illnesses and disabilities to express themselves more in a virtual environment, customising avatars for closer online relationships. The metaverse offers immersive, three-dimensional environments, enhancing mental health and alleviating the fear of missing out. The proposed "LOVE" framework aims to improve patient care using the metaverse (Fig. 5) (see Fig. 7).

L- Last-mile Enablement.
O - Organized Community.
V - Virtual Reality Playgrounds.
E – Extensive Monitoring and Fulfilment, as described in Fig. 1.

2.11. *Framework activities and its sub-activities (Fig. 6)*

2.11.1. *(L) Last-mile enablement*

Last-mile enablement in the metaverse allows patients to receive timely and budget-friendly treatment, mimicking the experience of a physical environment. Clinicians can compute trauma care and training activities in this virtual space. Service providers publish daily routines, set goals, and create digital avatars for patient profiles, fostering patient responsibility. With patient consent and anonymity, research institutes can study treatment responses to develop customized care techniques.

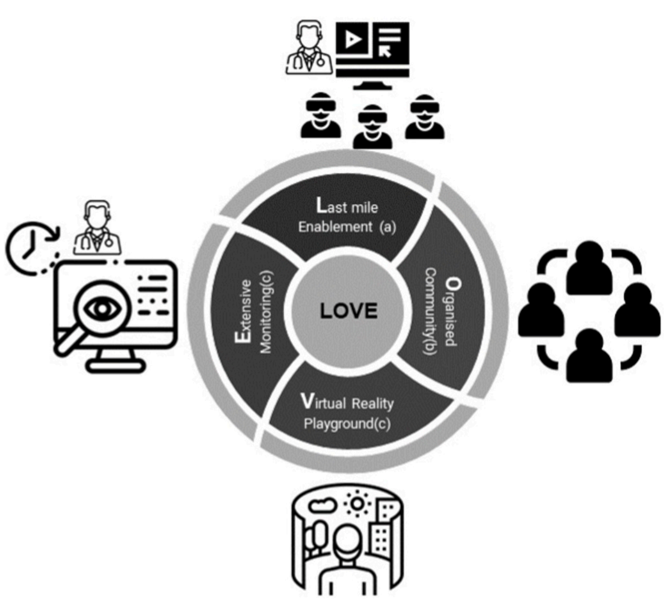

Fig. 5. LOVE framework to improve Quality of patient care using Metaverse.

2.11.2. *(O) Organised community*

A metaverse platform provides a community forum which allows patients to feel engaged and participative equally among themselves. In addition, Clinicians or healthcare agencies may provide counselling via digital avatars with anonymity.

2.11.3. *(V) Virtual Reality Playgrounds*

Physicians and healthcare professionals can use VR spaces to interact in a shared virtual environment. In the Metaverse, users can discuss medical data presented on a screen as an intractable visual representation in the real world. Involvement in virtual communities using VR gear, anonymous social media interaction, gaming to improve psychological conditions, and rewards exchanges among community members. This ecosystem must be self-sustaining by balancing subscription fees and the costs incurred by metaverse platforms to provide services.

2.11.4. *(E) Extensive Monitoring and Fulfilment*

Patients receive an activities checklist monitored by remote healthcare professionals, with rewards in fungible tokens redeemable on the platform. Remote monitoring includes behavior and care parameters, assigning Metaverse activities, applying clinical care, adjusting treatment based on Metaverse behavior, and selling non-fungible tokens for healthcare and research. Unique patient identification enables customized treatments, a key aspect of the LOVE framework. Healthcare professionals access real-time vital statistics, behavior, actions, and goals through a comprehensive set of tools in the LOVE framework, as depicted in Figs. 5 and 6.

2.12. *Key roles of metaverse in orthopaedics*

The metaverse is playing an increasingly significant role in the field of orthopaedics, revolutionizing how healthcare professionals approach diagnostics, treatment planning, and rehabilitation. In this virtual platform, orthopaedic specialists can utilise cutting-edge technologies such as virtual reality (VR) and augmented reality (AR) to create immersive simulations of anatomical structures and orthopaedic procedures (Fig. 8). Surgeons can practice complex surgeries in a risk-free environment, refining their skills and optimising their techniques before entering the operating room. 3D printing has already ensured that the physical models serve as great simulation tool and metaverse takes it to the next level[34,35] Additionally, the metaverse facilitates collaboration among medical professionals, allowing them to share insights and collaborate on complex cases in real time, transcending geographical boundaries. On the other hand, patients can benefit from virtual rehabilitation programs tailored to their specific needs and

Fig. 6. Illustrative tools to implement LOVE framework.

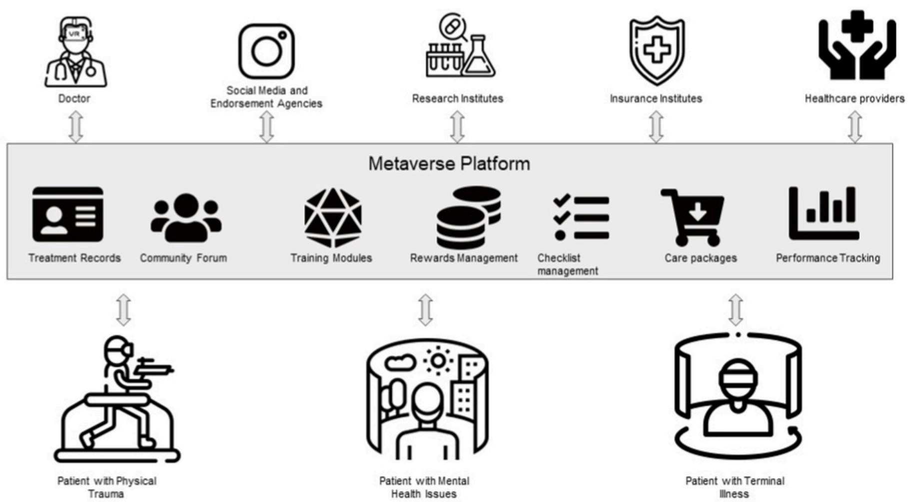

Fig. 7. LOVE framework-based Metaverse ecosystem.

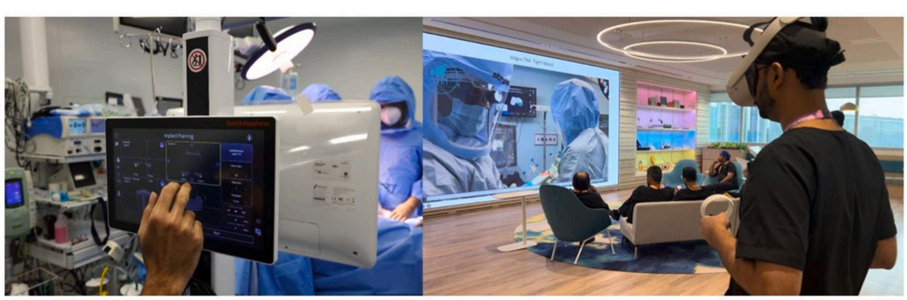

Fig. 8. Robotic knee surgery that used multiple enable technology like AR and VR.

monitored remotely by healthcare providers. Individual strengths, weakness and genetic predisposition can be incorporated in the Metaverse to ensure personalized care plans that optimise recovery outcomes. The metaverse thus presents a transformative paradigm in orthopaedics, enhancing precision, efficiency, and accessibility in the diagnosis and treatment of musculoskeletal disorders.

2.13. Proposed implementation in health metaverse – "the healthverse"

In "The Healthverse," a health-focused metaverse, digital asset tiles are built using the LOVE Framework. Platforms like Decentraland enable clinic owners to purchase virtual land, forming the pillars of the metaverse: environment and technology. Two pillars comprise the metaverse platform: the environment and technology. As illustrated in Fig. 6, the metaverse clinic is proposed to have three stakeholders:

- Clinic playground
- Patients
- Service providers

Virtual owners buy non-fungible tokens (NFTs) representing digital land assets on the metaverse platform for the clinic playground. 3D design adheres to platform standards, allowing the construction of buildings with built-in features. Patients, upon opening wallets, acquire collectables like avatars, reports, social profiles, and tokens for service payments.

Access controls vary for clinic staff, patients, and support personnel, facilitating interactions in labs, events, and with avatars representing clinicians. Collectables are available through wallets for immersive learning, digital art purchase, and interactions with digital humans for consultations and feedback.

Partners accessing patient information on the platform provide value-added services, financial support, insurance, and community forums for issue resolution. Patients, clinicians, and support staff engage with the Metaverse, offering value-added services. Patients are uniquely identified and tagged for customized treatments, a key LOVE framework indicator. Healthcare professionals access real-time data, aided by AI applications for monitoring and personalized care improvement.

2.14. Creating a healthverse: a beginner's guide!

Creating a healthverse involves purchasing metaverse virtual assets using cryptocurrencies like Ethereum, with platforms like Sandbox (using SAND) or Decentraland (using MANA). Virtual wallets such as Metamask and Binance store NFTs, confirming ownership through blockchain transactions. Third-party resellers like nonfungible.com and opensea. io act as real estate agents, ensuring secure ownership.

The following steps should be followed for making any purchase in metaverse:

i. **Open a Digital Crypto Wallet**: Choose a wallet compatible with your metaverse platform, such as MetaMask or Binance Chain Wallet.
ii. **Buy Cryptocurrency**: Acquire popular cryptocurrencies from exchanges like Binance or Coinbase.
iii. **Select a Metaverse**: Choose platforms like Decentraland or Sandbox, considering details like price, size, and ownership.
iv. **Confirm Your Purchase**: Visit the metaverse marketplace, click buy, and confirm the transaction. Your NFT ownership is then reflected in your wallet, securing your virtual property.

2.15. Limitations and roadblocks to universal adaptabilities

It is essential to understand the limitations of Metaverse technology, even though it has many potential benefits. As with any emerging technology, some potential challenges are associated with the Metaverse.

- Cybersecurity Concerns: Healthcare is a high-value target for cybercriminals, posing security risks.
- Infrastructure Requirements: Full system functionality demands a significant infrastructure investment.
- Cost of VR Technology: VR technology can be expensive compared to traditional education methods.
- Patient Attitudes: Patients may perceive online or remote treatment as inferior.
- High Cost of Wearables: Wearables and hardware like headsets can be costly, limiting accessibility.
- Affordability Barriers: Metaverse technology may be limited to those who can afford high infrastructure costs and quality connectivity.
- Elderly Population: Adapting new technology to the elderly, who are more vulnerable, poses a unique challenge.

2.16. Future perspective and the way forward

The metaverse is poised for impactful innovations in the future, shaping the way organizations expand and revolutionizing healthcare:

- Web3 Integration: Web3 technology enables decentralized web applications, empowering patients to control their identity and clinical data.
- Health 4.0 Advancements: AI, AR, and VR in the metaverse enhance patient safety outcomes and provide interactive insights into health conditions.
- Emergence of Spatial Computing: Utilizing AI, AR, VR, and 5G networks, spatial computing creates immersive online environments, transforming healthcare experiences.
- Transformational Force in Healthcare: Amid challenges like chronic diseases and resource limitations, the metaverse emerges as a transformative force in healthcare across clinical care, wellness, collaboration, education, and monetization.
- Digital Health Revolution: The metaverse drives a digital health revolution, transforming care methods and enabling pharmaceutical and biotechnology advancements.
- VR/AR in Medical Education: Virtual and augmented reality play crucial roles in developing training modules for clinicians and medical students, enhancing communication skills.
- Digital Twins for Predictive Healthcare: Digital Twins of patients, virtual replicas predicting behavior, stand central in the proposed model, serving individuals, groups, or machines as customers in healthcare.

3. Conclusion

Metaverse technology has significant potential for improving patient health and promoting equality. With such a large population, developing countries like India have yet to be recognised for their health disparities. The use of technology and real-time data streams will enhance the quality of patient care and the creation and analysis of data streams. Patients will be able to practice skills in a highly realistic environment through the use of virtual reality. In particular, virtual hospitals provide benefits to patients with mental health issues who are prone to non-compliance with their medication regimens. Patients and providers can identify emerging problems and reduce paperwork by tracking symptoms digitally. Metaverse is believed to open doors for all, expand opportunities, establish social networks, and improve mental health in the techno-health community. The potential of the metaverse is still speculative and dependent on various factors, from hardware deployment to data infrastructure. Through the metaverse, we will spend more time, energy, leisure, wealth, and existence in virtual worlds, which will exacerbate these issues. Thus, the need to collect and store more data is becoming increasingly important, or the risk of data loss will increase.

Funding

This research did not receive any specific funding

Ethical approval

Not Applicable.

Informed consent

This article does not contain any studies involving human subjects.

CRediT authorship contribution statement

Anjali Tiwari: Conceptualization, Formal analysis, Project administration, Resources, Validation, Visualization, Writing – original draft. **Ashutosh Dubey:** Conceptualization, Formal analysis, Validation, Visualization, Writing – original draft. **Amit Kumar Yadav:** Writing – review & editing. **Rakesh Bhansali:** Writing – review & editing. **Vaibhav Bagaria:** Supervision, Funding acquisition, Writing – review &

editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

None.

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