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Exploring the Awareness and Utilization of the Metaverse in Dentistry Among Dental Students and Professionals

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ABSTRACT

The integration of digital technologies within the metaverse is reshaping various fields, including dentistry, with the potential to drive significant advancements. This study aimed to investigate the level of knowledge, awareness, and comprehension of dental professionals and students regarding the metaverse's role in dental practice. Conducted as a cross-sectional survey, the research examined familiarity with metaverse-related technologies (such as XR, cloud computing, blockchain, digital twins, and AI) and their perceived impact on patient education, care, and training. A total of 328 participants including undergraduate and postgraduate dental students and faculty members participated in the study. Data collection was facilitated through a questionnaire shared through WhatsApp groups, comprising 28 questions covering demographic details, general knowledge, applications in patient education and care, implementation in dental training, and concluding insights. The findings indicated diverse levels of awareness, with most participants showing keen interest in integrating metaverse technologies into their professional and educational environments. However, concerns surrounding technical skills, data privacy, and security emerged as significant challenges to widespread adoption. These results underscore the importance of structured educational programs aimed at equipping dental professionals with the necessary expertise to harness metaverse technologies effectively, ultimately enhancing patient care and dental education.

Keywords: Dentistry, Metaverse, Patient care, Dental education, Patient education

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Introduction

With the rapid progression of digital advancements, the metaverse is known as a revolutionary concept, reshaping interactions with information and transforming virtual engagement. The term “metaverse,” derived from “meta” and “universe,” refers to a digital ecosystem that merges elements of both physical and virtual realities. Originally conceptualized in Neal Stephenson's speculative novel *Snow Crash* [1], the metaverse has evolved beyond fiction into a sophisticated network of digital technologies influencing multiple industries, including dentistry.

At its core, the metaverse is powered by XR, Blockchain, Cloud Computing, Digital Twins, and AI [2], introducing groundbreaking possibilities in patient care. Virtual consultations can bridge geographical gaps [3], immersive VR experiences can alleviate patient anxiety, wearable technologies can facilitate remote oral health monitoring, and Blockchain can enhance security in record-keeping [4]. In addition, patient education can be revolutionized through interactive digital campaigns, immersive VR tutorials, gamified applications, and virtual clinics, enabling individuals to better understand and manage their oral health.

In the realm of training and dental education, the metaverse provides hyper-realistic simulations and

collaborative learning spaces, equipping future professionals with hands-on experience to navigate real-world scenarios. This technological evolution signifies a paradigm shift in dental education, practice, and patient engagement. Given this transformation, the present study seeks to evaluate the awareness, perceived effectiveness, usability, and acceptance of metaverse applications in key dental areas, including patient care, education, and professional training.

Materials and Methods

Following Institutional Ethical Clearance, a structured questionnaire consisting of 28 carefully validated questions was designed to assess various aspects of metaverse applications in dentistry. The questionnaire was divided into sections covering demographic details, general inquiries, and perspectives on the integration of metaverse technologies in dental practice, patient care, training, and education. It was distributed via Google Forms through WhatsApp links, targeting postgraduate and undergraduate dental students, also dental professionals.

A total of 328 participants took part in the research, which was conducted between January 22 and January 31, 2024. The survey was an extensive literature review, followed by drafting, validation, and pilot testing to ensure clarity and reliability. Before participation, individuals were provided with detailed instructions on completing the questionnaire and informed consent was obtained to uphold ethical research standards. To maintain confidentiality, strict protocols were implemented to protect participants' demographic information.

Data analysis involved evaluating frequency distributions and percentages to identify patterns and trends in the responses. Additionally, statistical methods such as chi-square analysis and multiple logistic regression were applied to derive meaningful insights from the collected data.

Results and Discussion

The majority of participants fell within the 21-25 years age range (49.39%), followed by those aged 20 years or younger (39.94%). The participant pool was predominantly female, accounting for 74.09% of the total. In terms of academic status, most respondents were undergraduate students (63.11%), while postgraduates (18.29%) and interns (15.55%) made up the remainder.

When assessing general awareness of the metaverse, 57.6% of respondents reported familiarity with the concept. Regarding knowledge of specific technologies associated with the metaverse, artificial intelligence was the most recognized (78.5%), followed by extended reality (AR, VR, and AV) at 52.25%. However, a significant portion of participants (79.3%) had little to no awareness of metaverse applications within dentistry. Despite this, nearly all participants acknowledged its potential benefits, with 58.5% believing it could enhance patient care, 57% recognizing its value in patient education, and 68.6% supporting its role in dental education and training. These findings highlight both the existing knowledge gaps and the growing enthusiasm for integrating metaverse technologies to improve skills, efficiency, and overall proficiency in the dental field **(Table 1)**.

Table 1. Demographic and knowledge profile of study participants (n = 328)

Category	Number (%)
Age	
≤ 20 years	131 (39.94%)
21-25 years	162 (49.39%)
≥ 26 years	35 (10.67%)
Gender	
Male	85 (25.9%)
Female	243 (74.1%)
Academic/professional status	
Undergraduate students	207 (63.11%)
Interns	51 (15.55%)
Postgraduates	60 (18.29%)
Faculty members	10 (3.05%)
Total participants	328 (100%)
Prior awareness of the metaverse	
Yes	189 (57.6%)

No	139 (42.4%)
Familiarity with metaverse technologies	
Extended reality (AR, VR, AV)	149 (52.5%)
Blockchain	33 (11.6%)
Internet of things (IoT)	38 (13.4%)
Digital twinning	49 (17.3%)
Artificial intelligence	223 (78.5%)
Knowledge of metaverse applications in dentistry	
Yes	68 (20.7%)
No	260 (79.3%)
Perceived areas of use in dentistry	
Patient care	192 (58.5%)
Patient education	187 (57%)
Dental training and education	225 (68.6%)

Regarding the integration of metaverse technology in patient care, a significant portion of respondents highlighted its potential in delivering interactive, immersive, and personalized treatment experiences tailored to individual patient needs (62%). Other key applications identified included its role in improving treatment planning and diagnosis (59.1%), offering virtual walkthroughs of procedures before they are performed (47.1%), and managing patient anxiety (33.8%). Additionally, participants recognized its benefits in expanding access to dental specialists through tele-dentistry (31.8%), with lesser emphasis on its utility in pain management (23.1%), patient record management (23.1%), and surgical planning and reconstruction (26.6%).

A vast majority (84.8%) expressed willingness to integrate metaverse-based applications into their clinical practice. Further responses indicated strong confidence in the metaverse's role in enhancing pain management (72.6%) and increasing the precision of surgical procedures (85.7%). However, while awareness of blockchain for record-keeping was relatively low (69.2%), those familiar with the technology acknowledged its benefits, such as simplified record maintenance (62.4%), enhanced data security (52.2%), interoperability of health records (31.7%), and its potential use in disaster victim identification (22%). Notably, a large proportion of participants (63.4%) expressed interest in implementing blockchain technology in their dental practice **(Table 2)**.

Table 2. Analysis of metaverse applications

Component	Response	Number (%)
Metaverse in patient care		
Metaverse applications are beneficial for patient care in the following aspects:		
- Providing an interactive, immersive, and personalized experience	191	62%
- Enhancing treatment planning and diagnosis	182	59.1%
- Offering virtual walkthroughs of procedures	145	47.1%
- Expanding access to global dental specialists via Tele-dentistry	98	31.8%
- Aiding in patient anxiety management	104	33.8%
- Supporting pain management	71	23.1%
- Assisting in surgical planning and reconstruction	82	26.6%
- Streamlining patient record management	71	23.1%
Willing to integrate metaverse applications into clinical practice?	Yes	278 (84.8%)
	No	50 (15.2%)
Can metaverse be effective for pain management?	Yes	238 (72.6%)
	No	89 (27.4%)
Can metaverse improve surgical accuracy and precision?	Yes	281 (85.7%)
	No	47 (14.3%)

Awareness of blockchain in record-keeping	Yes	101 (30.8%)
	No	227 (69.2%)
Perceived benefits of blockchain in healthcare:		
- Simplified record management	128	62.4%
- Enhanced data protection	107	52.2%
- Interoperability of electronic health records	65	31.7%
- Identification of disaster victims	45	22%
Interest in using blockchain for practice	Yes	208 (63.4%)
	No	120 (36.6%)
Metaverse in patient education		
Can metaverse aid in oral health promotion?	Yes	294 (89.6%)
	No	34 (10.4%)
Can metaverse help reduce dental anxiety?	Yes	283 (86.3%)
	No	45 (13.7%)
Can metaverse encourage better oral hygiene habits?	Yes	287 (87.5%)
	No	41 (12.5%)
Will gamification make oral health education more engaging?	Yes	264 (80.5%)
	No	64 (19.5%)
Can metaverse help patients understand treatment procedures?	Yes	294 (89.6%)
	No	34 (10.4%)
Willingness to use metaverse for patient education	Yes	294 (89.6%)
	No	34 (10.4%)
Metaverse in dental training		
Awareness of metaverse applications for dental training	Yes	-
	No	-
Perceived benefits of metaverse in dental education:		
- Realistic virtual learning experiences	202	66%
- Hands-on practice for students	155	50.7%
- Use of haptic technology for manual dexterity	123	40.2%
- Virtual simulations of dental surgeries	141	46.1%
- VR-based 360-degree anatomical reconstructions	148	48.4%
- Interactive case-based learning	93	30.4%
Can metaverse improve students' skills and confidence?	Yes	299 (91.2%)
	No	29 (8.8%)
Will metaverse provide global access to dental education?	Yes	292 (89%)
	No	36 (11%)
Advantages of a metaverse in dental education:		
- Skill-based learning	238	76.8%
- Enhanced visual learning	168	54.2%
- Gamification for engagement	105	33.9%
- Creating an enjoyable learning environment	158	51%
Should metaverse be integrated into the dental curriculum?	Yes	296 (90.2%)
	No	32 (9.8%)
Willingness to use metaverse for dental training	Yes	296 (90.2%)
	No	32 (9.8%)

In terms of educating patients, a large portion (89.6%) of participants recognize the value of the metaverse in advancing oral health awareness. The technology is also seen as effective in alleviating dental anxiety

(86.3%) and helping patients grasp treatment details (89.6%). A notable 87.5% of those surveyed think that metaverse tools could support patients in cultivating better oral hygiene habits. Additionally, the same percentage (87.5%) believes that the use of gamification could increase both interest and awareness in oral health among the public. A majority (89.6%) is open to using metaverse tools for oral health education and promotion **(Table 2)**.

When it comes to dental training, 66.2% of respondents were aware of extended reality (XR) applications in this field. Many participants pointed out that the metaverse could offer valuable real-life learning experiences for students (66%) and enable hands-on practice (50.7%). Other benefits mentioned include virtual reality (VR) for anatomical 360-degree visualizations (48.4%), virtual surgery simulations (46.1%), haptic feedback technology for manual skill development (40.2%), and the creation of immersive scenarios that mirror real cases (30.4%). A significant 91.2% believe these applications will improve students' confidence and abilities, while 89% see the potential for widespread educational access. Among the various advantages, skill-based learning (76.8%) and visual learning (54.2%) were highly rated, with a good portion appreciating the enjoyable learning atmosphere (51%) and a smaller group recognizing gamification (33.9%). Around 90.2% of participants think the metaverse should become a standard part of dental education and are willing to embrace it for training purposes **(Table 2)**.

A large majority (91.8%) of participants believe that the metaverse, with its cutting-edge technological developments, holds significant promise for the future of dentistry. However, when reflecting on the potential challenges of adopting metaverse applications, several concerns were noted. These included the high cost of necessary equipment (59.5%), issues related to network security and privacy (53.1%), and to a lesser extent, challenges such as ethical considerations (39.5%), accessibility and usability (39.5%), lack of expertise (37.6%), and the absence of legislative frameworks (27.7%). Despite these concerns, most respondents (88.4%) expressed interest in integrating metaverse applications into patient care, dental education, and patient education. Interestingly, 63.7% of respondents indicated they were unaware of the Dentaverse platform, a metaverse solution specifically designed for dentistry **(Table 3)**.

Table 3. Summary of key questions

Key questions	Number (%)
Do you believe the metaverse, with its advanced technology, offers a promising future for dentistry?	Yes: 301 (91.8%) No: 27 (8.2%)
What do you see as the potential limitations of metaverse applications?	Expensive equipment: 185 (59.5%) Usability and accessibility issues: 123 (39.5%) Ethical challenges: 123 (39.5%) Network security and privacy concerns: 165 (53.1%) Lack of legislative restrictions: 86 (27.7%) Expertise shortage: 117 (37.6%)
Would you like to see metaverse applications integrated into dental education, patient education, and care?	Yes: 290 (88.4%) No: 38 (11.6%)
Are you familiar with the Dentaverse platform and Dental Design studio (sandbox), a metaverse application for dentistry?	Yes: 119 (36.3%) No: 209 (63.7%)

Among the 328 participants, 158 (48.17%) had a low level of knowledge (≤ 50%), while the remaining 170 (51.83%) had a high level of knowledge (> 50%) **(Figure 1)**. Educational qualifications were found to be a significant factor in determining knowledge levels. Postgraduate participants showed the highest level of knowledge compared to undergraduates and faculty, with this trend confirmed in both univariate and multivariate analyses. The odds ratio (OR) was 2.55, with a confidence interval (CI) between 1.03 and 6.27 (P = 0.0420*) **(Tables 4 and 5)**.

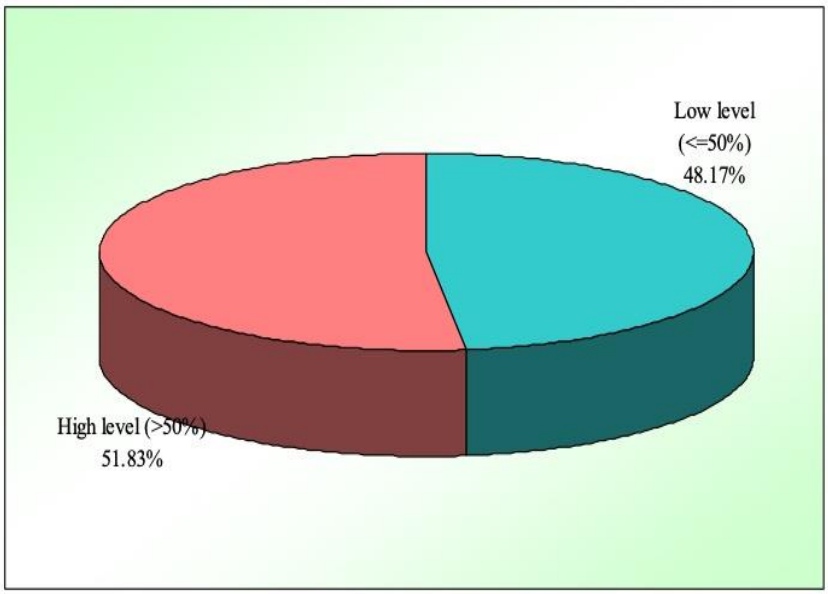

Figure 1. Graph depicting the level of knowledge related to metaverse in dentistry among the respondents.

Table 4. Relationship between knowledge levels and demographic characteristics of participants (chi-square analysis)

Demographic groups	Low level of knowledge (%)	High level of knowledge (%)	Total	Chi-square	P-value
Age groups					
≤ 20 years	58 (44.27%)	73 (55.73%)	131	4.4890	0.1060
21-25 years	81 (50.00%)	81 (50.00%)	162		
≥ 26 years	19 (54.29%)	16 (45.71%)	35		
Gender					
Male	33 (38.82%)	52 (61.18%)	85	1.5550	0.2120
Female	125 (51.44%)	118 (48.56%)	243		
Educational year (EQ)					
First-year	42 (50.60%)	41 (49.40%)	83	35.5210	0.0001*
Second-year	14 (35.90%)	25 (64.10%)	39		
Third-year	16 (42.11%)	22 (57.89%)	38		
Fourth-year	17 (36.17%)	30 (63.83%)	47		
Interns	28 (54.90%)	23 (45.10%)	51		
Postgraduates	36 (60.00%)	24 (40.00%)	60		
Staff	5 (50.00%)	5 (50.00%)	10		
Educational level (EQ)					
Undergraduates	89 (43.00%)	118 (57.00%)	207	10.4190	0.0150*
Interns	28 (54.90%)	23 (45.10%)	51		
Postgraduates	36 (60.00%)	24 (40.00%)	60		
Staff	5 (50.00%)	5 (50.00%)	10		
Total	158 (48.17%)	170 (51.83%)	328		

*Significant at P < 0.05

Table 5. Multiple logistic regression analysis of knowledge scores by various factors

Factors	High-level knowledge (%)	Adjusted OR	95% C.I. for OR	P-value
Age Groups				
≤ 20 years	58 (44.27%)	0.61	0.18-2.05	0.4270
21-25 years	81 (50.00%)	0.68	0.23-1.98	0.4810
≥ 26 years	19 (54.29%)	Ref.		

Gender				
Male	33 (38.82%)	Ref.		
Female	125 (51.44%)	1.36	0.83-2.24	0.2280
Educational year (EQ)				
Undergraduates	89 (43.00%)	1.44	0.45-4.65	0.5430
Interns	28 (54.90%)	0.87	0.27-2.83	0.8110
Postgraduates	36 (60.00%)	2.55	1.03-6.27	0.0420*
Staff	5 (50.00%)	Ref.		

*Significant at $P < 0.05$

The metaverse refers to a network of interconnected, immersive virtual worlds that are shared, allowing users to connect with friends, play games, engage in creative activities, shop, and work [5]. It is a computer-generated digital realm, facilitated by technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). This three-dimensional space is designed to be a communal area where avatars, which are digital representations of individuals, seamlessly transition between different experiences [6]. In simple terms, the metaverse is a simulated version of the real world. Its development is supported by six key technologies: extended reality for immersive experiences, artificial intelligence (AI) for interactive engagement, digital twins for creating virtual replicas, blockchain for security, telecommunication for connectivity, and cloud storage for scalability. Together, these technologies enable the metaverse to blend the physical and virtual realms, fostering collaboration and innovation across various industries. Bansal *et al*. [7] envision a future where advanced technology and wearables create more interactive, embodied, and multimodal digital experiences. They propose a broad approach to developing the metaverse, suggesting that it will mirror our real world, and offer a framework for healthcare.

Ullah *et al*. [4] discussed the challenges faced by the healthcare sector, including resource limitations, funding issues, and geographical barriers. They see the metaverse as a potential solution to these problems. Their study examines the metaverse's transformative possibilities, with a focus on its applications in healthcare, from education to clinical settings and surgeries. Additionally, they note a shift towards greater adoption of telehealth, reflecting the growing integration of technology in healthcare. Virtual reality, blockchain, and digital twins are highlighted as key components in reshaping healthcare practices.

Drawing from the advancements in healthcare, the use of the metaverse in dentistry is expected to evolve. It could eliminate the need for travel to dental clinics by offering virtual consultations, which would help reduce infection risks for both patients and healthcare providers, particularly during pandemics like COVID-19 [3]. Through the metaverse, individuals could consult with a dentist from the comfort of their own homes using VR headsets, reducing fear and anxiety, especially "white coat" anxiety.

The integration of metaverse technology into dentistry marks a significant shift in both patient care and professional development. The survey respondents' demographic data provide insight into the growing interest in metaverse technologies, particularly among younger age groups. A large portion of respondents were aged 21-25 years, with a notable number in the ≤ 20 years age range, reflecting the enthusiasm and familiarity younger generations have with emerging technologies.

The educational backgrounds of the respondents show that the majority come from undergraduate studies, suggesting that younger individuals, especially those early in their careers, are particularly interested in exploring the potential of metaverse technology in dentistry. Additionally, the presence of interns and postgraduates indicates that people at various academic and professional stages are also exploring the possibilities of the metaverse in this field.

Metaverse applications in patient care and education

While still in its early stages, the use of the metaverse in healthcare is gradually gaining attention. AR and VR technologies, in particular, have shown promise in enhancing patient engagement and education. These technologies can provide patients with a better understanding of their dental and medical conditions, potentially improving their treatment adherence and leading to better health outcomes [8, 9]. The results from this study highlight the wide-ranging potential of metaverse technology in patient care and education within dentistry. Respondents strongly supported the use of metaverse applications in clinical settings, identifying key benefits such as interactive service experiences, more efficient diagnosis and treatment planning, and the ability to offer procedural demonstrations. This demonstrates an acknowledgment of the significant advantages that

immersive technologies can bring to improving patient care and experiences.

Furthermore, the respondents were open to incorporating different elements of metaverse technology into their clinical practices, indicating a readiness to adopt these technologies in their workflows. Their confidence in metaverse applications for pain relief and enhancing the accuracy of surgical procedures further underscores the potential of these technologies to improve both clinical outcomes and patient well-being.

While many respondents were not fully aware of Blockchain technology's role in record-keeping, those who were familiar recognized its advantages, including easier management, stronger data protection, and the potential for interoperable health records. This suggests that Blockchain could play a key role in transforming record-keeping in dentistry, with many expressing interest in incorporating it into their practices. When it comes to patient education, the majority of respondents acknowledged the value of the metaverse in reducing dental anxiety, promoting oral health, and helping patients understand treatment procedures better.

Applications in dental training

Chen *et al.* [10] argue that merging traditional classroom teaching with immersive learning technologies in the metaverse could improve student interaction and learning, particularly in scientific fields and patient care. The findings from this study underscore how metaverse applications have the potential to radically change dental education and training.

Many respondents were familiar with Xtended Reality (XR) being used in dental training, showing an understanding of how immersive technology can fit into educational environments. Key benefits of incorporating metaverse into dental training included offering students authentic learning experiences, giving hands-on practice opportunities, enabling 360-degree views of anatomical structures through VR, and facilitating virtual surgery simulations. The importance of Haptic technology in enhancing manual skills and the ability to create interactive environments based on actual clinical cases were also highlighted as crucial elements for metaverse-based dental training. Additionally, respondents acknowledged the value of skill-building, visual-based learning, and fostering enjoyable learning experiences. Although not as prominent, the idea of using gamification to boost student engagement was also mentioned.

A significant number of participants expressed strong interest in having metaverse applications included in dental programs, indicating the importance they place on these technologies in shaping the future of dental education.

Challenges

The implementation of metaverse applications in dental practice also faces various challenges. The identified issues, such as the high costs of equipment, concerns around network security, privacy, and ethical dilemmas, highlight the practical and moral hurdles that need to be addressed to make these technologies viable. It's crucial to approach these challenges carefully to ensure the advantages of metaverse technologies are maximized while reducing potential risks.

Moreover, additional concerns were raised about the accessibility of these technologies, a lack of required expertise, and the absence of regulatory frameworks. Addressing these issues is vital to promote the seamless adoption of metaverse tools in dental practice.

Despite these challenges, the majority of respondents showed enthusiasm for integrating metaverse technologies into dental education, patient care, and patient education. By tackling these obstacles and enhancing awareness and skills within the dental community, metaverse applications can drive innovation, ushering in a new chapter of advancements in dental practice.

Evaluation of awareness

The results indicate that nearly half of the participants, about 48.17%, have a limited understanding of metaverse technologies, highlighting the necessity for targeted educational campaigns to fill this knowledge gap. Conversely, 51.83% of participants demonstrated a higher level of understanding, showing that a notable portion of the dental community is already acquainted with these emerging technologies. It's particularly noteworthy that educational level plays a key role, as postgraduate respondents showed a deeper understanding than undergraduates and faculty members. This suggests that advanced education contributes significantly to gaining expertise in new technologies, like the metaverse. Despite varying levels of awareness, there is a clear and strong interest in integrating metaverse innovations into dental training, patient care, and education.

Future prospects and challenges

This study's findings highlight the increasing enthusiasm for incorporating metaverse technology in

dental education, healthcare delivery, and patient engagement. As the technology matures, continued research is essential to explore its complete potential and address any challenges that may arise. Future research could focus on measuring the effectiveness of metaverse applications in improving clinical outcomes, enhancing patient understanding, and refining training processes for healthcare professionals. There should also be a focus on ensuring equal access to these tools and overcoming any adoption obstacles, particularly in underserved areas. The results suggest that metaverse technology could play a transformative role in healthcare and educational systems moving forward.

Conclusion

To sum up, the survey highlights a strong sense of optimism among participants about the potential of metaverse technologies to revolutionize the dental field. There is widespread support for incorporating this technology into various aspects of dentistry, including patient care, education, and professional practice. However, the study also identified several critical challenges, such as the high cost of equipment, concerns over network security and privacy, and other issues related to ethics, accessibility, expertise, and legal frameworks. Despite these challenges, respondents showed a keen interest in exploring how metaverse could be integrated into dental practices. Interestingly, many participants were unfamiliar with specialized platforms like Dentaverse, indicating a possible gap in awareness within the dental community. These findings emphasize the need to address both the promising opportunities and the obstacles facing the adoption of metaverse technology in dentistry. To fully harness its potential, it is crucial to focus on overcoming these limitations and increasing awareness within the dental profession.

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