RESEARCH ARTICLE

Exploring the knowledge and awareness on applications of virtual reality and augmented reality technology among dental healthcare professionals – a cross-sectional survey

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Abstract

Objective: To assess the knowledge and awareness of Virtual Reality (VR) and Augmented Reality (AR) technology in dentistry.

Methods: A questionnaire survey-based study was conducted using Google forms on a sample of 273 dental healthcare professionals (DHCP) from October- November 2023, after obtaining ethical approval. A validated questionnaire, divided into three sections, was used to assess the knowledge and awareness of dental healthcare professionals on virtual and augmented reality. Section A was about demographic statistics, section B assessed knowledge and awareness regarding VR and AR and section C consisted of future acceptability of VR and AR among DHCP. The frequency of each question was reported in percentages. To assess the difference of knowledge and awareness of AR and VR among different specialties of DHCP, one-way ANOVA test was applied and in case of significant results pairwise comparison was performed by post-hoc Tukey test.

Results: There was a statistically significant difference of knowledge (1.40 ± 0.49) among different dental healthcare professionals. On pairwise comparison, a statistically significant difference ($p = <0.05$) of knowledge and awareness of AR and VR was found among dental specialist and other dental health professionals.

Conclusions: A concerning lack of knowledge and awareness among dental healthcare professionals regarding AR and VR technology in dentistry was found. Interestingly, within the spectrum of specialties, dental specialists demonstrated a comparatively higher awareness than their counterparts in other specialties. Addressing barriers, notably a lack of knowledge, is crucial for successful technology adoption in dental education and practice.

Keywords: Augmented Reality, Virtual Reality, Dentistry, Education, Demography, Health Care, Variance, Technological Integration.

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Introduction

In the realm of digital dentistry, innovative applications and cutting-edge technology are rapidly expanding and evolving. When contemporary dentistry first emerged, 3D imaging and CAD/CAM applications were viewed as being particularly important.[1] However, computer simulations and artificial intelligence is another new chapter in the beginning of digital dentistry.[2] Applications for virtual simulation provide top-up information to the real world, opening up new potentials in the sphere of clinical practice and education in the field of medicine and surgery. Generally, in the field of virtual simulations humans visualize the objects that do not exist physically in the real world.[3] Among these technological advancements, Virtual Reality (VR) and Augmented Reality (AR) have gained prominence for their potential to revolutionize various aspects of dentistry.[4] AR creates a sensory perception by overlaying computer-generated virtual model on already existing physical model.[5] On the other hand, VR is an entirely artificial computer-generated model with real life surroundings.[6] VR is such a diverse technology with its two main features immersion and interaction that user feels an experience of real environment in a simulated model. By immersion a virtual model is created, and interaction refers to modifications required by the operator.[7] There are several systems using both the technologies AR and VR in the field of dentistry called mixed reality like IGI, Iris 100 and DentSim and Simodont.[8] (Fig 1)

AR/VR works on following closely interwoven elemental steps: data sourcing from real and virtual environment, tracing, registering, processing, perception locations as per customers demand and feedback mechanism.[9] AR/VR is not only commonly used in media industry for entertainments, explanation and simulated depiction but it is vastly being used in the field of medicine for invasive

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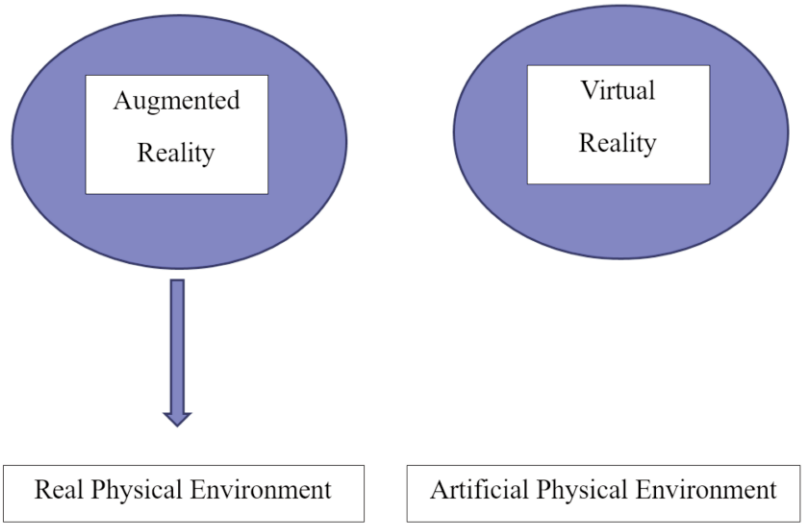

Figure:

approaches like laparoscopy and optical tracking system.[10] However, AR/VR are new technologies in the field of dentistry. Image guided intervention (IGI) is virtual simulation which helps in accurate image recognition and navigation to that image. IGI form of AR will aid in essential dental procedure from local anaesthesia block position to precisely locating the root apex during root canal therapy and identifying the bone during dental implant insertion.[11] Surgical planning precision will be immediately improved by AR/VR, which will ultimately increase prognosis and accuracy to achieve desired outcomes. Iris 100 technology was introduced to accurately track dental implants and lower the likelihood of failure by monitoring the depth and direction of the drill during surgery. In addition to the incredible therapeutic uses of AR/VR in the field of dentistry, this technology can significantly improve the educational system.[12] DentSim are virtual stimulatory labs to guide dental posture, instant feedback on procedure done on phantom, and collects this data to evaluate progress.[13] From an organizational standpoint, VR and AR not only integrate systems for learning and teaching, but also develop skills and enhance hand-eye coordination. Therefore, in order to lessen the difficulties encountered during crucial dental treatments, it is fundamentally important for dental teachers, students, and practitioners to be aware of new technologies like AR/VR.[14] To the best of our knowledge no study has yet been conducted to evaluate the knowledge and awareness of dental healthcare professionals regarding AR and VR. The primary objective of this study is to assess the difference in awareness and utilization of VR and AR technology among dental healthcare professionals, including dentists, dental educators, and dental students. The secondary objective is to determine the acceptance of dental healthcare professionals to incorporate VR and AR into their educational and clinical practices. The null hypothesis of our study is that dental health care professionals (DHCP) are well aware of AR and VR technology and reality to incorporate them in educational system and clinical practice.

Subjects and methods

After obtaining ethical approval from institutional ethical review board (2023-9332-26806), a survey-based cross-sectional study was carried out through Google Forms to evaluate the awareness of DHCP regarding artificial reality and virtual reality. The assessment was conducted on a validated questionnaire. The questionnaire was being validated by research specialists and dentists with research background. To establish content validity, we ensured that the questionnaire items were developed based on a comprehensive literature review and expert input. A face validity check was performed with five experts in the field. The questionnaire started with a consent question and then divided into three sections. General information concerning involvement in the DHCP was covered in Section A, knowledge and awareness of AR/VR was assessed in Section B, and acceptance of new, emerging AR/VR technology in the educational system and clinical practice was covered in Section C.

The sample size was determined by OpenEpi software[15], version 3.0 using the findings of Sadeep[16]. Assuming a population of 4000 where the hypothesized frequency of outcome factor in the population as 78 % regarding the awareness of machines based on latest virtual reality in dental education with a significance level of 5%, and a design effect of 1, the study required a sample size of 248 dental healthcare professionals. After 10% inflation we got a total sample size of 273 dental professionals. In this study we included dental healthcare professionals (e.g., dental students, general dentists, and dental specialists) with diverse experience levels, including seasoned professionals and those in training and we excluded all the subjects who did not respond after 3 reminders, incomplete responses and professionals not in practice for 5 years.

A Google doc link was sent to all the accessible dental students, general dentists and dental specialist meeting

the eligibility criteria through accessible social media platform like WhatsApp, Facebook pages and outlook mail. Over the course of a month, they received three gentle reminders. After the third reminder, the participant was excluded. Prior to the commencement of the survey, the first section was dedicated to obtaining consent from the participants. The participants were presented with the following consent statement:

"By completing this questionnaire, you are agreeing to participate in a study aimed at assessing the awareness and adoption of virtual reality (VR) and augmented reality (AR) technology within the context of dental healthcare practices. Your responses will contribute to a better understanding of the current landscape of VR and AR technology in the field of dentistry. Your participation in this study is voluntary, and all responses will be kept confidential. If you consent to participate, kindly proceed with answering the survey questions."

Statistical analysis

Data were gathered and organized into a Microsoft Excel file from a Google Form, where it was independently verified by two authors. Data were then transferred to SPSS software (Version 20.0, SPSS Inc. Chicago) and STATA® software for further analysis. After Shapiro-Wilk analysis we found that data were normally distributed. Descriptive for each qualitative question are reported in frequencies and percentages and quantitative questions are reported in means and standard deviations.

We assessed the difference of knowledge and awareness of AR/VR among dental students, general dentist, and dental specialists by one-way ANOVA test. In case of any significant value, pairwise comparison was performed by post-hoc Tukey analysis. A p-value < 0.05 was reported as statistically significant.

Results

The demographic profile of the study showcased a gender distribution of 100 males and 173 females, with males having an average age of 31.11 ± 6.00 years and females of 27.80 ± 4.37 years. Concerning clinical setups, 64 (23%) participants were affiliated with private clinical setups, 149 (54%) in private hospitals, and 60 (22%) in public hospitals. In terms of professional roles, the distribution included 116 (42%) general dentists, 10 (3.7%) dental students, 81 (29.7) residents, 26 (9.5%) specialists, 15 (5.5%) hygienists, 22 (8.1%) dental assistants and 3 (1.1%) dental technicians. (Table 1)

Participants' self-assessment of VR knowledge reflected diverse perceptions, with a noteworthy segment indicating limited or no knowledge. Practical experience

Table-1: Demographics.

Profession	Gender (Frequency)	Age (Mean, SD)	Experience	Workplace Frequency (Percentage)
General Dentist	Males = 29	29.52 ± 6.15	3.55 ± 3.72	PC = 55 (47.4)
	Females = 83	27.25 ± 3.41		PH = 42 (36.2)
				PuH = 19 (16.4)
Dental Student	Males = 2	24.50 ± 0.70	2.10 ± 1.10	PH = 3 (30)
	Females = 8	21.88 ± 0.99		PuH = 7 (70)
Dental Resident	Males = 26	28.27 ± 2.07	4.09 ± 2.23	PC = 3 (3.7)
	Females = 53	28.32 ± 2.07		PH = 52 (64.2)
				PuH = 26 (32.1)
Dental Specialist	Males = 15	38.20 ± 6.93	10.73 ± 4.98	PC = 2 (7.7)
	Females = 10	36.90 ± 6.15		PH = 20 (64.2)
				PuH = 4 (32.1)
Dental Hygienist	Males = 5	28.00 ± 3.67	3.93 ± 2.81	PC = 2 (13.3)
	Females = 9	24.22 ± 2.86		PH = 13 (86.7)
Dental Assistant	Males = 17	32.82 ± 3.89	12.5 ± 5.82	PC = 2 (9.1)
	Females = 5	29.00 ± 9.16		PH = 16 (72.7)
				PuH = 4 (18.2)
Dental Technician	Males = 3	35.67 ± 4.04	18.67 ± 4.04	PH = 3 (100)

PC = Private Clinics, PH = Private Hospital, PuH = Public Hospital
SD = Standard deviation

Table-2: Knowledge Awareness Questionnaire For DHCPs.

Q. No	Questions	Designation					
	GD	DS	DR	DSp	DH	DA	DT
Q.1 Have you heard of AR/VR technology being used in dentistry before taking this survey?							
Yes	66 (56.9)	6 (60)	51 (63)	26 (100)	7 (46)	7 (31)	2 (66)
No	50 (43.1)	4 (40)	30 (37)	0	8 (53)	15 (68)	1 (33)
Q.2 Have you ever used VR technology in your dental practice or education?							
Yes	29 (25)	3 (30)	8 (9)	10 (38)	3 (20)	5 (22)	1 (33)
No	87 (75)	7 (70)	73 (90)	16 (61)	12 (80)	17 (77)	2 (66)
Q.3 Have you ever used AR technology in your dental practice or education?							
Yes	19 (16)	2 (20)	4 (4)	11 (42)	1 (6)	7 (31)	1 (33)
No	97 (83)	8 (80)	77 (95)	15 (57)	14 (93)	15 (68)	2 (68)
Q.4 Have you ever attended a workshop, seminar, or training session on VR or AR in dental healthcare?							
Yes	27 (23)	2 (20)	3 (3)	11 (42)	2 (13)	7 (31)	1 (33)
No	89 (76)	8 (80)	78 (96)	15 (57)	13 (86)	15 (68)	2 (66)
Q.5 Would you be open to participate in research studies or trials related to VR and AR in dental healthcare?							
Yes	96 (82)	9 (90)	79 (97)	26 (100)	13 (86)	21 (95)	2 (66)
No	20 (17)	1 (10)	2 (2)	0	2 (13)	1 (4)	1 (33)
Q.6 Would you be interested in receiving training on the use of VR and AR in dental healthcare?							
Yes	104 (89)	9 (90)	80 (99)	26 (100)	13 (86)	21 (96)	2 (66)
No	12 (10)	1 (10)	1 (1)	0	2 (13)	1 (4)	1 (33)
Q.7 Are you aware of any specific VR or AR applications designed for dental education or practice?							
Yes	42 (36)	4 (60)	22 (27)	18 (69)	4 (73)	5 (22)	2 (66)
No	74 (63)	6 (40)	59 (72)	8 (30)	11 (26)	17 (77)	1 (33)

DHCPs = Dental Health Care Professionals, VR = Virtual Reality, AR = Augmented Reality, GD = General Dentist, DS = Dental Student, DR = Dental Resident, DSp = Dental Specialist, DH = Dental Hygienist, DA = Dental Assistant, DT = Dental Technician
(Response in frequencies & percentages)

with VR technology highlighted a significant gap, as 214 (78.4%) participants had not utilized VR, underscoring the disparity between awareness and implementation. Augmented reality (AR) technology also saw limited use, with 228 (83.5%) participants not incorporating it into dental practice.

Despite limited practical use, participants acknowledged the potential benefits of VR and AR in dental healthcare, particularly in enhanced education and reduced patient anxiety. Key barriers identified encompassed a lack of awareness, knowledge, and the high cost of technology. Familiarity with technical requirements for VR and AR implementation was generally low, with 193 (70%) participants indicating a lack of familiarity. Participants exhibited varying readiness to incorporate VR and AR, with 246 (90%) open to research participation and 255 (93%) participants expressing interest in training on these technologies. (Table 2)

On comparing the awareness among different DHCPs, a highly significant difference ($p \leq 0.05$) was observed in awareness among all the groups (Table 3). The results from comparative analysis showed a statistically significant difference in awareness levels ($p \leq 0.05$) among dental specialists as compared to their other counterparts (Table 4).

Table-3: Knowledge & Awareness among DHCPs

Questions	Mean, SD	p-value
Have you heard of virtual reality (VR) technology being used in dentistry before taking this survey?	1.40 ± 0.49	< 0.001**
Have you ever used VR technology in your dental practice or education?	1.78 ± 0.41	0.05*
Have you ever used AR technology in your dental practice or education?	1.84 ± 0.37	< 0.001**
Have you ever attended a workshop, seminar, or training session on Virtual Reality (VR) or Augmented Reality (AR) in dental healthcare?	1.81 ± 0.39	< 0.001**
Are you aware of any specific VR or AR applications designed for dental education or practice?	1.64 ± 0.47	0.004**
On a scale of 1 to 5, how would you rate your current knowledge of virtual and augmented reality technology in dentistry?	2.23 ± 1.17	< 0.001**

VR = Virtual Reality, AR = Augmented Reality, SD = Standard Deviation,
DHCP = Dental Health Care Professional
$p \leq 0.05$*, $p \leq 0.001$**,
One Way ANOVA

Table-4: Comparative Analysis of Knowledge & Awareness among DHCPs.

Questions		DHCP	p-value
Have you heard of virtual reality (VR) technology being used in dentistry before taking this survey?	DSp	GD	< 0.001**
		DR	0.01*
		DH	0.01*
		DA	< 0.001**
Have you ever used VR technology in your dental practice or education?	DSp	DR	0.03*
Have you ever used AR technology in your dental practice or education?	DSp	GD	0.01*
		DR	< 0.001**
		DH	0.03*
Have you ever attended a workshop, seminar, or training session on VR or AR in dental healthcare?	DR	GD	< 0.001**
		DS	< 0.001**
		DA	0.03*
Are you aware of any specific VR or AR applications designed for dental education or practice?	DSp	GD	0.02*
		DR	0.002*
		DA	0.01*
On a scale of 1 to 5, how would you rate your current knowledge of virtual and augmented reality technology in dentistry?	DSp	GD	< 0.00**
		DR	< 0.001**
		DA	0.01*

VR = Virtual Reality, AR = Augmented Reality, DHCP = Dental Health Care Professional,
GD = General Dentist, DS = Dental Student, DR = Dental Resident, DSp = Dental Specialist, DH = Dental Hygienist, DA = Dental Assistant
$p \leq 0.05$*, $p \leq 0.001$**,
Post-Hoc Tuckey

Discussion

This study explored virtual and augmented reality awareness in dentistry among dental health care professionals, aiming to discern potential variations

among distinct professional groups. Initially, we hypothesized that dental healthcare professionals possess significant awareness of AR and VR technology for seamless integration into education and practice. However, our findings contradicted this hypothesis. Examining awareness levels in dental specialists, residents, and general dentists revealed significant differences, challenging the notion of uniform awareness.

The identification of significant differences in virtual reality awareness among dental specialists, residents, and general dentists prompts a closer examination of potential contributing factors. One plausible explanation for these variations could be the diverse exposure and training received by each group in their respective professional settings. Dental specialists may benefit from specialized educational programmes or professional development opportunities that incorporate virtual reality applications, leading to a heightened awareness compared to their counterparts. In contrast, general dentists, dealing with a broader range of dental procedures, may prioritise different aspects in their education, resulting in differing levels of virtual reality awareness.

Sadeep et al.[16] in their study focused on awareness of virtual reality machines in dental education, our research took a broader perspective, exploring VR and AR applications in dentistry. While they reported 78% awareness among dental professionals, our study revealed nuanced awareness levels among general dentists, dental residents, and dental specialists, showcasing notable variations. Simultaneously, 66% of participants in our study expressed unawareness of specific VR or AR applications designed for dental education or practice, such as dental simulation software. Conversely, among those familiar with such applications, notable mentions included Guided AR, VR headsets, dental simulator, Simodont, Blue Sky, and Perfect Smile. These diverse responses illuminate the varied landscape of awareness within the dental community regarding existing VR and AR applications.

In a study by Orhue et al.[17] participants expressed a high level of openness to the use of distraction virtual reality, with 84.5% indicating a willingness to receive training. Similarly, in our study, 87%, expressed openness to participate in research studies or trials related to VR and AR in dental healthcare. Additionally, our study found an even higher level of interest in training, with 91% of participants indicating a desire to receive training on the use of VR and AR in dental healthcare. These parallel findings highlight a strong inclination among dental professionals to embrace and engage with virtual reality technologies for training and research purposes.

In a study conducted by Antony et al.[18], perceptions of the effectiveness of dental simulators were assessed, revealing that 38% of respondents expressed a neutral opinion. This neutral stance, including participants who had not used simulators, contrasts with our study, where 32% showed neutrality. However, their study showed a higher positive perception, with 57% considering simulators effective or very effective, in contrast to our study's 30%. This discrepancy could be attributed to various factors, such as differences in participant backgrounds, exposure to simulator technology, or variations in the specific aspects of simulators assessed in each study.

In a study by Lund et al.[19], students rated the realistic reproduction of mandibular third molar surgery in an oral surgery simulator just above average. Despite this, they found the exercise in the simulator fruitful and developing, indicating its potential in oral and maxillofacial undergraduate training. In contrast, our study, focussed on dental healthcare professionals, found that a large number of participants identified oral surgery as the field benefitting most from VR/AR technologies. Respondents emphasized the significant advantage of these technologies in treatment and surgical planning, aligning with the potential applications discussed in their study. This parallel recognition highlights the value of technology-enhanced training in oral surgery applications across both professional and student perspectives.

The finding in the study by Udoye et al.[20] emphasizing inadequate knowledge on the use of VR in dental practice, aligns with the sentiments expressed in our study. Both studies recognize a deficiency in awareness as a potential hindrance to the adoption of VR technologies in the dental field. The acknowledgment of poor awareness as a contributing factor, as reported in their study, resonates with our participants' identification of the "lack of awareness and knowledge" as a predominant barrier to the adoption of VR and AR in dental practice. This convergence in findings underscores the critical need for targeted educational initiatives to address the awareness gap and enhance the integration of VR technologies in dental healthcare.

In our study, when questioning participants about their belief in the potential impact of AR/VR technologies on the future of dental healthcare, a majority expressed agreement. This sentiment echoes the findings of a study by Nkenke et al.[21], on the acceptance of virtual dental implant planning software, where dental students

demonstrated a pragmatic approach, focusing on the usefulness of technology to their practice. Moreover, when gauging participants' readiness to incorporate AR/VR technologies, 45% indicated a readiness level ranging from ready to very ready. This convergence underscores the pivotal role perceived usefulness plays in shaping the acceptance and readiness for emerging technologies in the dental profession.

This groundbreaking study marks the first exploration of virtual reality awareness in dentistry within our regional context, adding a distinctive regional perspective to the global discourse. Its pioneering nature contributes not only to the broader understanding of virtual reality in healthcare but also provides insights shaped by the specific characteristics of our dental community. Additionally, the identification of barriers and the diverse perspectives on the potential benefits of VR and augmented reality (AR) technologies enrich the current understanding of factors influencing the adoption of these technologies in dental practice and education. and comparison of virtual reality awareness among diverse dental professionals.

However, it is essential to acknowledge certain limitations. The reliance on self-reported responses may introduce a potential subjective bias, as participants might provide socially desirable answers or not accurately reflect their actual awareness levels. While informative, the sample size may not fully capture the diversity of the broader dental community, limiting the generalizability of the findings. Despite these limitations, this study serves as a foundational step, providing crucial insights into the current state of virtual reality awareness in dentistry. It sets the stage for future research to address specific gaps and explore strategies for bridging the awareness-practice divide within the dental healthcare landscape in our region.

Conclusion

This study unveils disparities in virtual reality (VR) and augmented reality (AR) awareness among dental professionals. With a substantial segment indicating limited knowledge and practical exposure, targeted interventions are imperative to enhance integration. The differences among specialists, residents, and general dentists underscore the nuanced nature of awareness. Overcoming barriers, such as a lack of knowledge, is crucial for the effective adoption of these technologies in dental education and practice.

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