EXPLORING VIRTUAL REALITY IN DENTAL EDUCATION: PERCEPTIONS AND USABILITY AMONG UNDERGRADUATE STUDENTS

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ABSTRACT

Background: Clinical education in dentistry is predominantly mannequin-based. Inability to develop clinical skills owing to lack of patients and high operating costs, among other factors, creates a gap. In recent days, VR is gaining prominence as a viable solution to bridge this gap.

Objectives: The objective of the study was to investigate the effectiveness of VR alongside usability of technology and barriers to VR integration among undergraduate dental students of the Liaquat College of Medicine & Dentistry (LCMD).

Methods: The study was a cross-sectional, institutional based survey. Data was collected using a validated questionnaire (16 items) from 216 students of Bachelor of Dental Surgery (BDS). The survey collected data on the demographics, barriers related to the VR, clinical context, and VR. Analysis was done using SPSS version 22.0. The study employed descriptive analysis and Pearson's Chi-Square tests ($p < 0.05$).

Results: The study achieved a response rate of 216 (118 females, 98 males). Out of the total respondents, 110 students reported using VR in the past, whereas 106 students had never used VR. 47 students reported VR implementation in their institution, whereas 101 students reported its absence and 68 students were indifferent. Based on frequency distribution, 86 students reported never using it, 43 used it on occasion, 9 used it on a frequent basis, and 78 students reported VR usage. 144 students reported that VR improved their understanding of human anatomy. 162 students reported that VR improved their clinical/practical skills, and 158 students reported that VR improved their engagement levels when compared to the traditional teaching methods. 158 students were in favor of further integration of VR in their curriculum, and 121 students supported the total replacement of mannequin-based simulations by VR.

Conclusion: Undergraduate dental students reported very positive views toward VR. The two major barriers in the design and structure of VR are the high cost of institutional implementation and technical issues.

Keywords: virtual reality, dental education, undergraduate students, perception

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1- BACKGROUND OF STUDY:

An effective dental education system carries theory with practical interventions in a clinical context (1). In many cases, students learn over

the foundations of basic knowledge and then move onto hands-on classes such as practice on phantom heads or clinical practice (1,2). While mannequin-based simulators can build up basic skills, they have issues such as limited case scenarios, high costs, and require a lot of instructor involvement (3,4).

Pre-clinical training can now be reinforced with high-fidelity and interactive digital tools thanks to existing educational technology (5). Virtual Reality (VR) can build high-fidelity and interactive simulations (6). VR can help students in dentistry experience a clinical situation and get real-time guidance without posing a threat to the patient (7). VR can improve all of these skills and confidence through its immersiveness (8,9).

Though VR can be seamlessly integrated into dentistry training worldwide, there are still issues of cost effectiveness and long term positive skill retention for incorporating VR into mainstream curricula (10).

VR along with haptics are fully integrated across multiple other health care disciplines thanks to the technology and emerging curricula (5). In terms of adoption and curriculum flexibility, studies of haptic VR systems in education show high student satisfaction and appreciation for 3D training (3,11). However, students still tend to see virtual environments as supplements rather than full replacements for phantom heads (3). This shows that, while training systems are important for initial learning, the substitute for physical contact is needed.

More research supports the finding that High-Fidelity Virtual Simulation (HVRS) is useful in the pre-clinical phase of training, particularly in the development and acquisition of control in the use of tools and manipulative procedures. It has been found that early exposure can actually facilitate the learning of the skills involved (6, 8, 12). The digital revolution has led to an increasing trend of providing educational resources as digital platforms. Digital resources are rapidly becoming an investment in educational technology (5). Standardizing digital technology within institutions is critical to quality control and consistency of education (10). VR simulation in training promotes confidence and improves skill retention, but the relative expense of initial set up and control of the technology are limiting factors to widespread use (10). The study is focused on perceptions and barriers to the use of technology and the barriers to integration of VR simulation for undergraduate dental students at the Liaquat College of Medicine and Dentistry (LCMD).

2- METHODOLOGY:

2.1 Study Design and Setting

A prospective descriptive design was used for this study, alongside a cross-sectional approach. This study was conducted in the academic departments of the Liaquat College of Medicine & Dentistry (LCMD).

2.2 Data Collection Tools

Data collection was done by a pretested, validated, online structured questionnaire titled "Questionnaire on Role of Virtual Reality (VR) in Dental Education". The self-administered online questionnaire was developed and it consisted of 16 items in total, segmented into 5 zones (domains) based on institutional validation by Imran et al. (2024).

Domain A: Demographics and Baseline Characteristics (Items 1–3):

Age (Item 1), biological sex (Item 2), and year of study from BDS 1st year to 4th year (Item 3).

Domain B: Structures of Exposure and Level of Infrastructure (Items 4–7):

Level of personal VR use (Item 4), status of personal VR use within the institution's dental program (Item 5), the use of VR for education (Item 6), and the type of VR educational sub-modality (Item 7).

Domain C: Usability and the Effects of VR on Learning (Items 8–11):

Items addressing the impact of VR on learning dental anatomy (Item 8), the enhancement and refinement of learning/clinical manual skills (Item 9), the VR system's capability to be user-friendly, and VR's capacity to sustain learner's interest (Item 10) and the ease of system navigation (Item 11).

Domain D: Technical Issues, the VR Learning System, and the Learning Curriculum (Items 12–14):

The occurrence of latency during the VR system (Item 12), the desire of students to learn using VR, and the replacement of the VR system with traditional teaching using mannequins (Item 13) and students' opinions regarding the possibility of the VR system replacing traditional teaching (Item 14).

Domain E: Implementation Barriers and Future Suggestions (Items 15–16):

Reviewed organized multiple-selection checklists concerning procurement limitations (Item 15) and provided an open-ended qualitative feedback space (Item 16).

2.3 Data Collection Procedure

The survey was created using Google Forms and then was circulated through official channels of the institution. Participants digitally signed their consent to participate and then were allowed to access the survey items. Data was collected for a specified period in the 6 month

duration of the study after the Institutional Review Board (IRB) approved it.

2.4 Framework for Statistical Analysis

Data was collected through surveys and then was exported using an SPSS (Statistical Package for Social Sciences) version 22.0, then was manually cleaved and coded. Continuous univariate data was assessed using descriptive statistics in the form of frequency and percent. Inferential data was analyzed using the Pearson Chi-square (X^2) to identify any statistically significant relationships that may exist between the independent variables (the different academic seniority levels) and the dependent variable (the areas of concern) at a statistically significant level of $p < 0.05$.

3- RESULTS

Table 1: Characteristics of the Survey Participants (n=216)

The table below shows the demographics of the survey participants. Data was collected based on Age, Gender and Year of study, and was done in the survey of n=216 sample participants.

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Female	118	54.7%
	Male	98	45.3%
Age Distribution	18 Years	22	10.4%
	19 Years	22	10.4%
	20 Years	29	13.2%
	21 Years	22	10.4%
	22 Years	27	12.3%
	23 Years	33	15.1%
	24 Years	31	14.2%
	25 Years	30	14.2%
Year of Study	1st Year BDS	49	22.6%
	2nd Year BDS	53	24.5%
	3rd Year BDS	57	26.4%

	4th Year BDS	57	26.4%

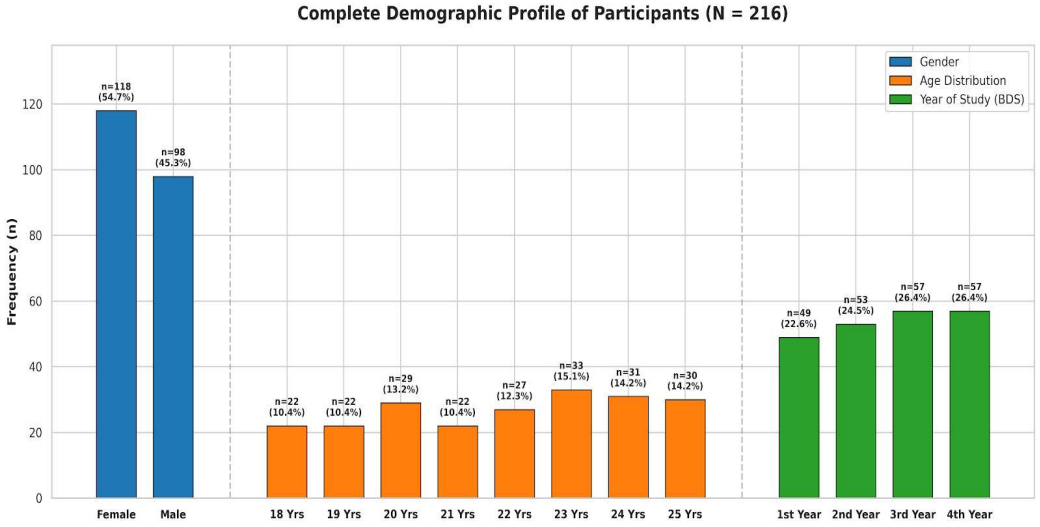


Table 2: Prior Exposure and Institutional VR Implementation (n=216)
This table lists the baseline exposure characteristics of respondents with respect to previous usage and the condition of integration into the institution.

Questionnaire Item	Response Option	Frequency (n)	Percentage (%)
Item 4: Have you previously used VR?	Yes	110	51.0%
	No	106	49.0%
Item 5: Institutional implementation status	Yes	47	21.9%
	No	101	46.7%
	Not sure	68	31.4%
Item 6: Frequency of VR utilization	Rarely	86	40.0%
	Occasionally	43	20.0%
	Frequently	9	3.8%
	Never	78	36.2%

Table 3: Distribution of VR Modalities Utilized by Trainees (n=216)
This table presents the particular technical forms of the Dental Students' engagement with Virtual Reality (allowing respondents to select multiple options).

Technical Modality Category (Item 7)	Count (n)	Sample Percentage (%)
3D Virtual Models	82	38.1%
Fully Immersive VR	33	15.2%
Augmented Reality (AR)	19	8.6%
Haptic Simulation	12	5.7%
None	70	32.4%

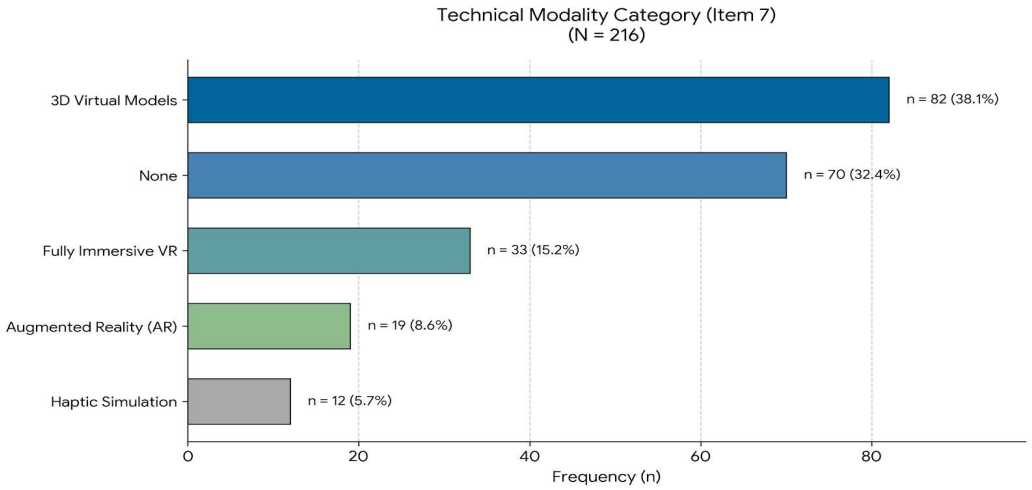


Table 4: Perceived Usability and Pedagogical Effectiveness (n=216)
This table provides feedback on the main utility features, ease of navigation within the system, and the system's instructional value.

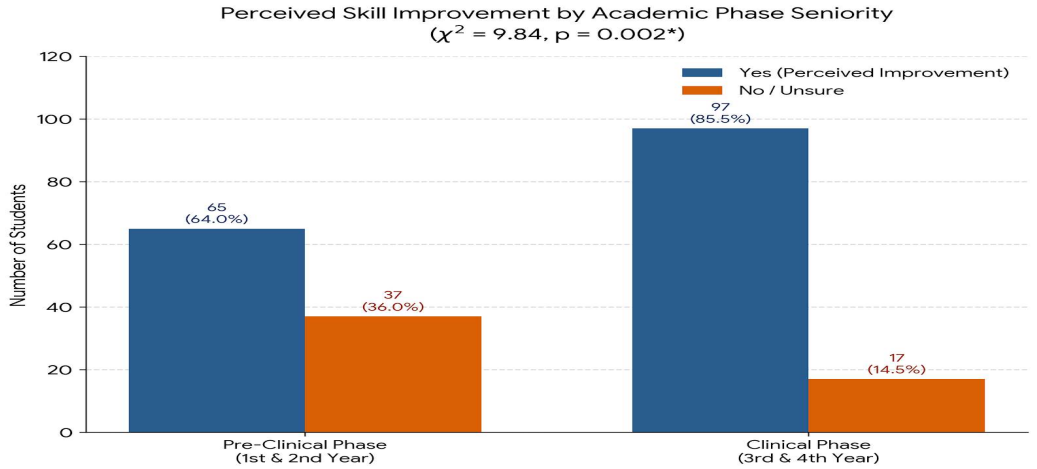
Core Usability Domain Indicator	Yes (n, %)	No (n, %)	Not Sure (n, %)
Item 8: Enhances dental anatomy comprehension	144 (66.7%)	19 (8.6%)	53 (24.8%)
Item 9: Helps improve practical/clinical skills	162 (75.2%)	16 (7.6%)	38 (17.1%)
Item 10: Improves engagement over traditional methods	158 (73.3%)	23 (10.5%)	35 (16.2%)
Item 11: System is simple to use and navigate	121 (56.2%)	23 (10.5%)	72 (30.5%)

Table 5: Cross-Tabulation of Practical Skill Perception by Academic Phase (n=216)
This table illustrates the results of the inferential Chi-square distribution, which examines the relationship between the seniority of the academic phase and the perception of positive improvement of practical skills (item 9).

Academic Phase Seniority	Perceived Skill Improvement (Yes)	Perceived Skill Improvement (No/Unsure)	Chi-Square Value (X2)	p-value
Pre-Clinical Phase (1st & 2nd Year)	65 (64.0%)	37 (36.0%)		

Clinical Phase (3rd & 4th Year)	97 (85.5%)	17 (14.5%)	9.84	**0.002***

Statistically significant at $p < 0.05$



4- DISCUSSION

This study evaluated the initial experiences, usability, and challenges of incorporating virtual reality (VR) into the training of undergraduate dental students at LCMD. The results indicated a strong level of engagement with 75.0% (162/216) of the respondents reporting that VR assisted in the development of their practical and clinical skills. This was also the finding of Roy et al., (2017) when they reported that early exposure to haptic-enhanced virtual environments expedited the development of procedural skill (6).

VR had a positive impact on the students' foundation of dental learning. Approximately two-thirds (144/216) of the respondents believed that VR assisted them in understanding human anatomy, while also reporting (158/216) that VR increased their level of engagement when compared to traditional teaching methods. This was also reported by Al-Saud et al. (2017) and Urbankova (2010), stating that 3D virtual reality assisted in Spatial Learning in a pre-clinical environment.

Interestingly, 56.0% of respondents (121/216) indicated a preference to replace the traditional mannequin phantom with the VR simulation. This was in contrast to Murbay et al. (2020), where the students considered VR a supplemental tool to traditional phantom stations and not a full replacement. Possibly, the students at LCMD were operating under more limited resources, and were therefore more used to replacing traditional phantoms with virtual 3D models. (3).

Although participants showed high enthusiasm, many reported both technical and structural issues. A number of participants reported issues with software lag and system latency. As noted by both Li (2021) and Rhienmora et al. (2011), haptic feedback and technical reliability are important for both learning and the maintenance of the confidence of the user (10,11). Additionally 46.8% of participants (101/216) reported high costs of acquisition and lack of systematic implementation of the technology (101). As reported in the dental simulation literature, this presents a significant financial barrier (10). As a result, the best contemporary dental education approach combines traditional phantom heads with digital simulations (2,4).

5- CONCLUSION

This study indicates that undergraduate dental students demonstrated a good understanding of the usefulness of Virtual Reality in the development of fine motor skills to facilitate learning in the classroom and the understanding of anatomy. Students endorse its integration throughout the existing dental pathways as a significant new technology.

6- RECOMMENDATIONS

In light of this, the following recommendations have been made:

- **Development of a Blended Curriculum**: Dental schools should begin to include compulsory 3D virtual modeling as a preparatory bridging module prior to students undertaking live patient diagnostic work.
- **Support of the Technical Infrastructure**: Hardware should be employed to ensure that latency is low and that software crashes are

minimized to ensure good haptic tracking.

- **Faculty Development**: There should be an organized series of workshops that are aimed to develop skilled Faculty to create Mentors who are capable to facilitate and guide automated, simulation based feedback in the Academic center.

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