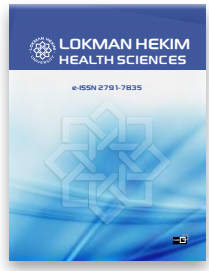
LOKMAN HEKIM HEALTH SCIENCES

DOI: 10.14744/lhhs.2026.72774
Lokman Hekim Health Sci 2026;6(4):605–613



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ORIGINAL ARTICLE

Evaluation of Tooth Preparation in a Haptic Three-Dimensional Virtual Reality Dental Training Simulator: A Questionnaire Study

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Abstract

Introduction: This study aimed to evaluate the use of a three-dimensional (3D) haptic virtual reality (VR) dental training simulator for tooth preparation practice in preclinical dental education.

Methods: Fifty-six 4th-year dental students at Lokman Hekim University used the Virteasy VR dental training simulator to perform a tooth preparation on the mandibular canine. Participants subsequently completed an 18-item questionnaire assessing four categories: Content, anatomy, applicability, and usability. Descriptive statistics and Fisher's exact test were used to analyze questionnaire responses and examine associations with demographic variables.

Results: Most participants rated the simulator positively in terms of content quality, anatomical accuracy, and usability. Female participants particularly highlighted its potential for future development and its ability to facilitate control over tooth preparation processes. Statistically significant correlations were found between specific questionnaire items, indicating parallel scoring trends among participants. In addition, students reported that the simulator enhanced clinical skills and reduced the gap between model practice and real patient scenarios. Most participants did not report discomfort, such as headaches, during use.

Discussion and Conclusion: The haptic 3D VR dental simulator is a valuable educational tool that complements traditional methods in dental education. It offers advantages such as reduced material waste, enhanced anatomical understanding, and opportunities for repeated practice.

Keywords: Dental education; Preclinical training; Tooth preparation; Virtual reality

Virtual reality (VR) is a three-dimensional (3D) computer-generated system that enables users to perceive, interact with, and experience immersion in a simulated setting. This system is used in entertainment fields such as gaming and media, as well as in education and health.[1,2] The use of the system, especially in the field of education, has been reported to increase academic achievement.[3]

Cite this article as: *Güngör Erdoğan H, Özer NE, Şahin Z, Akçin ET, Çiçekci G. Evaluation of Tooth Preparation in a Haptic Three-Dimensional Virtual Reality Dental Training Simulator: A Questionnaire Study. Lokman Hekim Health Sci 2026;6(4):605–613.*

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E-mail: gngr.hamiyet@gmail.com **Submitted:** 24.06.2025 **Revised:** 18.02.2026 **Accepted:** 03.03.2026 **Available Online:** 14.09.2026

In dental education, not only the acquisition of theoretical knowledge but also the development of fine motor skills is essential. Before treating patients in the clinic, students are expected to gain adequate competence through preclinical training.[4] One of the core practical competencies taught during this phase is tooth preparation.[5] This procedure requires substantial practice and experience to preserve tooth structure and to avoid pulp damage.[6] However, traditional training with typodonts or extracted teeth is limited by material costs, sterilization challenges, and the need for continuous supervision. These limitations highlight the need for innovative teaching tools that provide both efficiency and reproducibility.

VR-based training simulators have emerged as promising solutions to these challenges. They minimize the reliance on physical materials, potential sterilization issues when working with extracted teeth, reduce costs, and allow procedures to be repeated under standardized conditions.[7] Beyond technical practice, VR simulators also enable students to engage in self-assessment through immediate and end-of-procedure feedback, thereby promoting independent learning and skill refinement.[8] In addition, this application provides students with the opportunity to examine and learn the anatomy of the oral environment, a subject that can be challenging to observe and study. VR applications offer several advantages, such as the ability to perform operations repeatedly and the absence of occupational health and safety risks.[1] The literature claims that practical application videos and the use of microscopes, in addition to VR applications, aid students in developing their skills.[9,10]

This study aimed to evaluate the effectiveness of a haptic 3D VR training simulator in preclinical dental education. Specifically, it aimed to investigate students' experiences and perceptions regarding tooth preparation practice, focusing on how the simulator supported their learning, skill development, and self-assessment. The null hypothesis was that the VR simulator would not have a significant impact on students' evaluations and perceived educational benefits.

Materials and Methods

The study investigating the use of a haptic 3D VR dental training simulator for tooth preparation in preclinical education was approved by the Lokman Hekim University Scientific Research Ethics Committee (Decision: 2023101, Date: 13.06.2023).

The study was carried out with the 4th-year dental students from the Faculty of Dentistry at Lokman Hekim University who participated in the study. The inclusion criteria for this study required participants to be 4th-year dental students enrolled in preclinical courses, to have completed standard preclinical tooth preparation training on mannequins, and to have provided written informed consent. All participants had performed tooth preparation on real patients as part of clinical training. Exclusion criteria included having prior experience with the Virteasy VR dental simulator or having any physical or visual condition that would prevent effective use of the VR simulator. Participants were shown how to use various hardware components of the Virteasy (Laval, Pays De La Loire, France) haptic VR dental training simulator. Participants were then asked to answer all the questions in the questionnaire. The Lawshe technique was used to test content validity in the study, and five expert opinions were evaluated. The content validity index (CVI) value was calculated for each item in the study and obtained as 1.00. The minimum CVI for the five experts is 0.99. The calculated CVI value was compared to 0.99, and no items with low validity or requiring modification were found. To achieve the aim of this study, an original questionnaire was created, building on the foundations provided by the works of literature published in the same field.[1] Informed consent was obtained, and anonymity of responses was ensured.

The participants were asked to perform crown preparation of the right lower mandibular canine tooth without a time limit. On average, participants spent 20–30 min on the task. To record post-preparation experiences and opinions, the questionnaire was answered by the students. The questionnaire contained four sections: "content, anatomy, applicability, and usability." In the content section, the quality of the content of the training simulation was evaluated; in the anatomy section, the accuracy of the anatomical structure of the oral cavity and dental morphology during the practice was determined. In the applicability section, the attractiveness of the practical training was evaluated by determining the applicability and ease of use of the simulator for the practical training. In the usability section, the effects of practicing using the VR simulator felt by the participant and the realism similarity of the practice were reviewed. Each item was evaluated on a 5-point Likert scale ranging from 0 to 4, where 0 indicated "strongly disagree," 1 "disagree," 2 "neutral," 3 "agree," and 4 "strongly agree."

Analyses of the survey questions were carried out in the IBM Statistical Package for the Social Sciences 25 (IBM Corp, Armonk, NY, USA) program. The study used descriptive statistics (number and percentage) of the data. In addition

Table 1. The distribution of responses to the content section questions and their association with gender

Content	Scores	Total n (%)	Female n (%)	Male n (%)	p
Q1- Is the accuracy of the tooth preparation simulator acceptable when compared to the actual clinical results?	0	2 (3.5)	0 (0.0)	2 (100.0)	0.359
	1	9 (15.8)	7 (77.8)	2 (22.2)	
	2	17 (31.6)	12 (70.6)	5 (29.4)	
	3	16 (28.1)	11 (68.8)	5 (31.3)	
	4	12 (21.1)	7 (58.3)	5 (41.7)	
Q2- Is it possible to check the whole process of the tooth preparation in the simulator?	0	3 (5.3)	0 (0.0)	3 (100.0)	0.042*
	1	10 (17.5)	9 (90.0)	1 (10.0)	
	2	15 (28.1)	10 (66.7)	5 (33.3)	
	3	16 (28.1)	12 (75.0)	4 (25.0)	
	4	12 (21.1)	6 (50.0)	6 (50.0)	
Q3- Is the practice of using HMDs more beneficial when compared to traditional practice (using dentiforms)?	0	7 (12.3)	4 (57.1)	3 (42.9)	0.938
	1	7 (12.3)	5 (71.4)	2 (28.6)	
	2	13 (24.6)	9 (69.2)	4 (30.8)	
	3	17 (29.8)	12 (70.6)	5 (29.4)	
	4	12 (21.1)	7(58.3)	5 (41.7)	
Q4- Is the practice of using haptic devices more beneficial when compared to the existing practice (using dentiforms)?	0	2 (3.5)	0 (0.0)	2 (100.0)	0.359
	1	12 (21.1)	10 (77.8)	2 (22.2)	
	2	10 (15.8)	7 (70.6)	3 (29.4)	
	3	17 (31.6)	11 (68.8)	6 (31.3)	
	4	15 (28.1)	9 (58.3)	6 (41.7)	

*: p<0.05. HMD: Head mount display.

to descriptive statistics, potential associations between survey responses and gender were also examined. Fisher's exact test was used to evaluate associations between categorical variables when the assumptions required for the chi-square test were not met. A one-sample chi-square test was applied to test the differences between the proportions of responses to categorical variables. The level of statistical significance was set at p<0.05. The study was conducted in accordance with the Declaration of Helsinki.

Results

A total of fifty-six 4th-year dental students (37 females, 19 males) attended the study. When the demographic characteristics of the participants were analyzed, 66.1% of the participants were female and 33.9% were male. 94.7% of the participants were between 20 and 23 years old, and 5.3% were between 18 and 20 years old. Among the questions in the "content" section of the questionnaire, Q1 (Is the accuracy of the dental preparation simulator acceptable when compared to actual clinical practice results?) was rated as score 2 by 31.6%, and Q4 (How would you rate the effectiveness of the use of dental simulators in preclinical education in the acquisition of clinical skills?) was rated as score 3 by 31.6% (Table 1). In the "Anatomy" section of the questionnaire, Q7 (A 3D anatomical model is likely to be helpful in understanding anatomy) was marked at score 3 with the highest rate of 40.4% (Table 2). In the "applicability" section of the questionnaire, Q13 (the tooth preparation simulator is likely to be further developed in the future) was recorded at score 4 with the highest percentage of 47.4% (Table 3). Finally, in the "Usability" section of the questionnaire, 45.6% answered score 3 to Q17 (I did not feel pain, dizziness, or headache when I practiced) (Table 4).

In determining the association between the questions in the questionnaire, the scores given to the questions Q3 (Is the application of VR-based simulation technology more useful in developing students' preclinical skills compared to the current traditional practice?) and Q11 (I think that the current dental education curriculum should include the application using the VR simulator) in the applicability section were compared with Fisher's exact test, and a statistically significant association was found between the answers (p<0.05). 57% of those who gave a score of 0 to

Table 2. The distribution of responses to the anatomy section questions and their association with gender

Anatomy	Scores	Total n (%)	Female n (%)	Male n (%)	p
Q5- The structure of the tooth corresponds to the real anatomical structure.	0	0 (0.0)	0 (0.0)	0 (0.0)	0.330
	1	6 (12.3)	4 (66.7)	2 (33.3)	
	2	14 (24.6)	12 (85.7)	2 (14.3)	
	3	18 (31.6)	10 (55.6)	8 (44.4)	
	4	18 (31.6)	11 (61.1)	7 (38.9)	
Q6- The shape of the teeth is similar to the actual patient.	0	0 (0.0)	0 (0.0)	0 (0.0)	0.956
	1	1 (1.8)	1 (100.0)	0 (0.0)	
	2	13 (22.8)	8 (66.7)	4 (33.3)	
	3	22 (38.6)	15 (68.2)	7 (31.8)	
	4	21 (36.8)	13 (61.9)	8 (38.1)	
Q7- A three-dimensional anatomic model is likely to be helpful in understanding anatomy.	0	0 (0)	0 (0)	0 (0)	0.799
	1	4 (7.1)	3 (75.0)	1 (25.0)	
	2	7 (12.5)	4 (57.1)	3 (42.9)	
	3	23 (41.0)	14 (60.9)	9 (39.1)	
	4	22 (39.2)	16 (72.7)	6 (27.3)	

question Q3 also gave a score of 0 to question Q11. Again, 100% of those who answered score 4 to question Q3 also answered score 4 to question Q11 (Table 5). In addition, as a result of the analysis of the scores given to the questions Q4 (how would you evaluate the effectiveness of the use of dental simulators in preclinical education in the acquisition of clinical skills?), and Q10 (the use of a VR simulator is useful to reduce the difference between clinical practice in real patients and model practice) with Fisher's exact test, a statistically significant association was determined between the answers ($p<0.05$). 100% of those who answered a score of 0 to question Q4 also answered a score of 0 to question Q10. In answering these questions in Tables 5 and 6, parallelism was found in the scoring of the participants.

A significant difference was found between gender and questions Q2 (is it possible to control the whole process of tooth preparation in the simulator?) and Q13 (there is a possibility of further development of the tooth preparation simulator in the future) ($p<0.05$) (Tables 1 and 3). Female participants significantly stated that it is possible to control the whole process of tooth preparation in the simulator and that there is a possibility of further development of simulators for tooth preparation in the future compared to male participants.

Discussion

This study aimed to evaluate students' perceptions of a haptic 3D VR dental training simulator in preclinical tooth preparation practice and to examine its perceived educational value in comparison with traditional training methods. The null hypothesis, which stated that the use of the VR simulator would not significantly influence students' evaluations and perceived educational benefits, was rejected. The findings demonstrated statistically significant associations among several questionnaire items and generally positive student perceptions regarding the simulator's content quality, anatomical representation, applicability, and usability. These results suggest that the integration of haptic VR simulation into preclinical dental education may enhance students' learning experiences and support skill development.

In the present study, students who performed tooth preparation using a VR simulator evaluated their experiences under four categories: Content, anatomy, applicability, and usability. The transition from preclinical to clinical education in dentistry is the most important and exciting moment during the student period. At this point, the profession commences its professional practice. Dental practices perform procedures that demand a high level of hand sensitivity and experience. To gain the ability to perform procedures in a very small area, students must first work in structures that mimic the patient's intraoral environment and gain experience. In this way, it is aimed to increase adaptation and success during the transition from preclinical to clinical training.[11]

Today, there are many digital technologies such as VR devices, augmented reality, mixed reality, and extended reality that are increasingly integrated into dental education.[12,13] It is important to evaluate the contribution

Table 3. The distribution of responses to the applicability section questions and their association with gender

Applicability	Scores	Total n (%)	Female n (%)	Male n (%)	p
Q8- The process of practicing with the simulator is interesting.	0	1 (1.8)	1 (100.0)	0 (0.0)	0.853
	1	5 (8.8)	4 (80.0)	1 (20.0)	
	2	9 (15.8)	7 (77.8)	2 (22.2)	
	3	18 (33.3)	11 (61.1)	7 (38.9)	
	4	23 (40.4)	14 (60.9)	9 (39.1)	
Q9- It is beneficial for learning the tooth preparation process.	0	4 (7.0)	2 (50.0)	2 (50.0)	0.812
	1	6 (10.5)	5 (83.3)	1 (16.7)	
	2	10 (19.3)	6 (60.0)	4 (40.0)	
	3	17 (29.8)	12 (70.6)	5 (29.4)	
	4	19 (33.3)	12 (63.2)	7 (36.8)	
Q10- Using this VR simulator is helpful to reduce the gap between clinical in actual patients and model practice.	0	7 (12.3)	5 (71.4)	2 (28.6)	1.000
	1	4 (7.0)	3 (75.0)	1 (25.0)	
	2	8 (14.0)	5 (62.5)	3 (37.5)	
	3	18 (33.3)	12 (66.7)	6 (33.3)	
	4	19 (33.3)	12 (63.2)	7 (36.8)	
Q11- I think that the existing dental education curriculum should include the practice using the VR simulator.	0	6 (10.5)	3 (50.0)	3 (50.0)	0.588
	1	4 (7.0)	4 (100.0)	0 (0.0)	
	2	10 (17.5)	7 (70.0)	3 (30.0)	
	3	17 (31.6)	10 (58.8)	7 (41.2)	
	4	19 (33.3)	13 (68.4)	6 (31.6)	
Q12- I want to learn other dental practices using VR simulator.	0	3 (5.3)	1 (33.3)	2 (66.7)	0.494
	1	4 (7.0)	4 (100.0)	0 (0.0)	
	2	9 (17.5)	6 (66.7)	3 (33.3)	
	3	20 (35.1)	14 (70.0)	6 (30.0)	
	4	20 (35.1)	12 (60.0)	8 (40.0)	
Q13- There is a possibility of future development of the tooth preparation simulator.	0	1 (1.8)	1 (100.0)	0 (0.0)	0.041*
	1	2 (3.5)	0 (0.0)	2 (100.0)	
	2	8 (14.0)	8 (100.0)	0 (0.0)	
	3	19 (33.3)	11 (61.1)	7 (38.9)	
	4	27 (47.4)	17 (63.0)	10 (37.0)	

*: $p<0.05$. VR: Virtual reality.

of these developing digital systems to the education of students, and there are many studies in the literature on the application and results of these technologies.[14,15] Similar to the present study results, in other studies, the use of VR haptic dental simulators has advantages such as students being able to practice safely and independently with these devices, standardization of the education received, patient safety, and reduction of waste materials.[16,17] The system can be used in many dental disciplines such as endodontics, pedodontics, and prosthodontics. Dental education is a continuous process, and distance education is not possible. In the event of a global pandemic such as COVID-19, it is very important to use VR haptic simulation technologies so that education is not affected.[18] In addition, thanks to this technology, there are situations where it is possible to train and practice outside of the faculty's teaching hours.[12]

In dental education, extracted teeth are frequently used as educational material. However, as a result of the developments in dentistry and the awareness of patients, the tendency to protect teeth and keep them in the mouth has increased. Therefore, it will become more and more difficult to find extracted teeth used as training material

Table 4. The distribution of responses to the usability section questions and their association with gender

Usability	Scores	Total n (%)	Female n (%)	Male n (%)	p
Q14- In practice, HMD felt comfortable.	0	3 (5.3)	0 (0.0)	3 (100.0)	0.128
	1	5 (8.8)	4 (80.0)	1 (20.0)	
	2	9 (15.8)	5 (55.6)	4 (44.4)	
	3	25 (43.9)	18 (75.0)	6 (25.0)	
	4	15 (26.3)	10 (66.7)	5 (33.3)	
Q15- The quality of the video at the time of practice is good.	0	1 (1.8)	0 (0.0)	1 (100.0)	0.439
	1	3 (5.3)	1 (33.3)	2 (66.7)	
	2	12 (21.1)	9 (75.0)	3 (25.0)	
	3	24 (42.1)	16 (66.7)	8 (33.3)	
	4	17 (29.8)	11 (68.8)	5 (31.3)	
Q16- The operation using the haptic device is similar to the operation of the actual handpiece.	0	4 (7.0)	3 (75.0)	1 (25.0)	0.502
	1	5 (8.8)	2 (40.0)	3 (60.0)	
	2	13 (22.8)	7 (53.8)	6 (46.2)	
	3	17 (29.8)	13 (76.5)	4 (23.5)	
	4	18 (31.6)	12 (70.6)	5 (29.4)	
Q17- I did not feel aching, dizziness, or headache when I practiced.	0	0 (0)	0 (0)	0 (0)	0.716
	1	4 (7.0)	3 (75.0)	1 (25.0)	
	2	4 (7.0)	3 (75.0)	1 (25.0)	
	3	26 (45.6)	18 (72.0)	7 (28.0)	
	4	23 (40.4)	13 (56.5)	10 (43.5)	
Q18- Practice using the VR simulator seemed comfortable.	0	5 (8.8)	2 (40.0)	3 (60.0)	0.133
	1	6 (10.5)	6 (100.0)	0 (0.0)	
	2	9 (15.8)	7 (77.8)	2 (22.2)	
	3	21 (36.8)	14 (70.0)	6 (30.0)	
	4	16 (28.1)	8 (50.0)	8 (50.0)	

HMD: Head mount display; VR: Virtual reality.

Table 5. The distributions of individuals' responses to the 'Is the practice of using HMDs more beneficial when compared to traditional practice (using dentiforms)? "and" I think that the existing dental education curriculum should include the practice using the VR simulator' questions and the association between them

	Scores	Q3- Is the practice of using HMDs more beneficial when compared to traditional practice (using dentiforms)?					
		0 n (%)	1 n (%)	2 n (%)	3 n (%)	4 n (%)	p
Q11- I think that the existing dental education curriculum should include the practice using the VR simulator.	0	4 (57.1)	1 (14.3)	0 (0.0)	1 (5.9)	0 (0.0)	<0.001*
	1	2 (28.6)	0 (0.0)	2 (14.3)	0 (0.0)	0 (0.0)	
	2	0 (0.0)	1 (14.3)	3 (21.4)	6 (35.3)	0 (0.0)	
	3	0 (0.0)	3 (42.9)	7 (50.0)	8 (47.1)	0 (0.0)	
	4	1 (14.3)	2 (28.6)	2 (14.3)	2 (11.8)	12 (100)	

*: p<0.05. HMD: Head mount display; VR: Virtual reality.

and to use them in applications. There are studies indicating that VR haptic simulation training has an equivalent effect on extracted teeth in improving minimally invasive caries cleaning, providing equal benefit to traditional simulations.[19–23] On the other hand, some studies have shown an improvement in manual dexterity with the use of VR. There

Table 6. The distributions of individuals' responses to the "Is the practice of using haptic devices more beneficial when compared to existing practice (using dentiforms)? "and" Using this VR simulator is helpful to reduce the gap between clinical in actual patients and model practice" questions and the association between them

	Scores	Q4- Is the practice of using haptic devices more beneficial when compared to the existing practice (using dentiforms)?					
		0 n (%)	1 n (%)	2 n (%)	3 n (%)	4 n (%)	p
Q10- Using this VR simulator is helpful to reduce the gap between clinical in actual patients and model practice.	0	2 (100)	3 (25.0)	0 (0.0)	2 (11.1)	0 (0.0)	<0.001*
	1	0 (0.0)	1 (8.3)	2 (22.2)	1 (5.6)	0 (0.0)	
	2	0 (0.0)	3 (25.0)	1 (11.1)	3 (16.7)	1 (6.3)	
	3	0 (0.0)	3 (25.0)	3 (33.3)	10 (55.6)	3 (18.8)	
	4	0 (0.0)	2 (16.7)	3 (33.3)	2 (11.1)	12 (75.0)	

*: p<0.05. VR: Virtual reality.

are also studies in the literature that recommend the VR method be used in combination with mannequin models rather than instead of traditional mannequin models.[24,25] In the current study, more than half of the students found the VR-based simulation more useful than the traditional method. They also stated that the simulator contributed to understanding the anatomy of the region they studied.

In the present study, the participants, especially the female students, believed that the simulator could be improved in the future. As the application develops, it is thought that it will provide more benefits as an educational material. Such technological systems are very interesting and motivating for a generation that is intertwined with digital games.[26,27]

The fact that the system allows for an objective assessment and repetition will increase the number of training hours and lead the student to a better point in the learning curve. In addition, it is thought that the benefit of the system will increase as the simulated scenarios get closer to reality. In the current study, a significant portion of the students had the idea that the use of dental simulators in preclinical education would increase their skills in the clinic. In studies in which repeated applications were evaluated, it was reported that the duration was shortened, virtual cavity performance increased, and the perception of errors improved.[11] Similarly, in the current study, more than half of the students reported that their clinical skills would increase with the use of simulators. Female students believed this idea more than male students.

Studies have been conducted on head-mounted displays in simulator training. Within the studies, participants were asked whether they felt visual discomfort, and findings of eye pain, nausea, and headache were reported.[28] In the current study, the majority of participants (n=49) reported that they did not feel a headache during the application (Q17). More than half of the participants also found the app comfortable to use (n=37) (Q18).

The contribution of this study is its structured evaluation of student experiences across four dimensions (content, anatomy, applicability, and usability) within a preclinical setting. While many previous studies have focused primarily on technical performance, the present research provides insights into how VR simulation may influence students' perception of anatomy, clinical applicability, and motivation, offering a complementary perspective to the existing literature.

The present study found that female participants reported higher agreement than males regarding the controllability of the simulator (Q2) and the potential for its future development (Q13). This finding aligns with observations in dental education that gender may influence attitudes toward technology-enhanced learning. For example, Nassani et al.[29] reported that gendered differences exist in responses to technology teaching in dentistry, indicating potential variation in acceptance and engagement. Similarly, in a recent VR clinical observation study, women showed significantly greater procedural understanding scores than men in the VR group (p=0.007).[30]

However, the present study has several limitations that should be considered when interpreting these findings. The questionnaire was applied to a limited population, and the number of female participants was greater, which could have biased the results. In addition, the simulator was used only for a limited experience, which restricts the generalizability of the findings. It is possible that repeated or routine use of the simulator in dental training might positively influence students' scoring and reduce such gender-related differences. Therefore, the gender differences observed in the present study should be

interpreted with caution, and future research with larger, gender-balanced cohorts and repeated simulator exposure is needed to validate these trends.

Conclusion

The study revealed that the students were optimistic about the advancement of these technologies and believed that this situation would enhance dentistry education. However, it is thought that VR technology is not yet used as a stand-alone educational material, but it is a very important and complementary educational tool, and its continuous use for all branches of dentistry will increase success.

Ethics Committee Approval: The Lokman Hekim University Scientific Research Ethics Committee granted approval for this study (date: 13.06.2023, number: 2023101).

Informed Consent: Written informed consent was obtained.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

Use of AI for Writing Assistance: Not declared.

Authorship Contributions: Concept: HGE, NEÖ, ZŞ, ETA, GÇ; Design: HGE, NEÖ, ZŞ, ETA, GÇ; Supervision: HGE, NEÖ, ZŞ, ETA, GÇ; Resource: HGE, NEÖ, ZŞ, ETA, GÇ; Materials: HGE, NEÖ, ZŞ, ETA, GÇ; Data Collection or Processing: HGE, NEÖ, ZŞ, ETA, GÇ; Analysis or Interpretation: HGE, NEÖ, ZŞ, ETA, GÇ; Literature Search: HGE, NEÖ, ZŞ, ETA, GÇ; Writing: HGE, NEÖ, ZŞ, ETA, GÇ; Critical Review: HGE, NEÖ, ZŞ, ETA, GÇ.

Peer-review: Double blind peer-reviewed.

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