Protocol

Immersive Reality–Based Training Simulator for Dental Extraction: Protocol for a Randomized Pilot Trial

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Abstract

Background: Dental students’ competencies are shaped by their training, yet traditional methods with mannequins often lack the depth necessary for comprehensive understanding, potentially impacting clinical proficiency. Immersive reality (IR) innovatively offers interactive and scenario-based environments that may enhance skill acquisition.

Objective: This study evaluates the effectiveness of IR-based training implementation in comparison with conventional training methods for dental extractions.

Methods: A prospective multicenter randomized clinical trial was conducted. Students were randomized to either IR-based training on open and closed extractions or conventional hands-on tutorials by oral surgeons. Post training, participants’ satisfaction and understanding were assessed and analyzed.

Results: As of September 2025, 60 students from Hasanuddin University, Makassar, and Padjajaran University, Bandung, have been enrolled, and study enrollment will be expanded to Universitas Sumatera Utara, Medan. Data collection is ongoing and will conclude in November 2025, with expected dissemination in early 2026.

Conclusions: IR-based training offers a novel approach that may boost motivation, knowledge retention, and skill transfer in dental education. This pilot protocol explores IR’s feasibility and potential to advance dental students’ competencies.

Trial Registration: Indonesian Clinical Research Registry INA-QES4CC5; https://ina-crr.kemkes.go.id/en/studi/207

International Registered Report Identifier (IRRID): DERR1-10.2196/74978

(JMIR Res Protoc 2025;14:e74978) doi: 10.2196/74978

KEYWORDS

dental extraction; immersive reality; pilot trial; virtual training; study protocol

Introduction

Dental extraction is among the most frequently performed procedures in dental practice [1]. Indications for extraction are diverse, including periodontitis, endodontic complications, orthodontic needs, ectopic eruption, prosthetic treatment planning, traumatic injury, and systemic conditions, with dental caries being the most common cause [2-4]. The high prevalence of extractions underscores the importance of equipping dental students with sufficient knowledge, technical proficiency, and clinical competence [5,6].

Conventional training methods and passive observation restrict students' ability to understand the complexity of treatments, particularly within the confined working environment of the oral cavity [7,8]. Moreover, novice dental students often lack familiarity with assisting tasks, reducing training efficiency and learning outcomes. Effective skill acquisition requires not only theoretical knowledge but also spatial imagination, active engagement, and repeated practice opportunities [9-11]. Consequently, extensive training and prolonged clinical exposure are often necessary before dental students achieve the level of competence required to provide safe and effective oral health care [12,13].

Immersive reality (IR), which integrates virtual reality and augmented reality, has emerged as a promising educational technology to overcome these challenges [14-17]. IR provides a safe, realistic, and hands-on platform for students to practice clinical procedures and refine their skills [18-25]. Evidence suggests that IR-based training improves practical competence, treatment planning, and standardized assessment while offering repeatable and engaging learning experiences [26-30]. Importantly, IR technology supports consistent training for complex procedures that demand precision and manual dexterity [31-33]. By addressing limitations of conventional learning—such as high costs, limited patient cases, and restricted opportunities for repeated practice—IR can bridge gaps in skill acquisition, foster collaboration, and enhance creativity in clinical training [34-38].

Despite these advantages, the application of IR as a simulator for dental extraction training remains insufficiently explored. To date, IR technology has been implemented in operative dentistry, periodontology, and dental radiography for practices such as tooth drilling, endodontic cavity access, crown placement, and periodontal procedures [39-43]. Furthermore, none of these applications involves students from multicenter institutions. This study seeks to highlight the use of IR training for dental extractions involving students from multicenter institutions while also generating feedback for further refinement of the simulator and its associated training protocol.

Methods

Apparatus

Unity 3D Engine software (Microsoft Corporation) was used as the platform for simulating dental extraction procedures in an IR environment. This platform enables users to engage from a first-person perspective. In the virtual environment, users can interact with 3D models by using either hand gestures or controllers.

In this study, the IR hardware setup consists of a personal computer featuring an Intel Core i7-11800H chipset and an NVIDIA GeForce RTX 3080 graphics card, which includes a GPU with 10 GB of GDDR6X memory. The configuration also incorporates a Meta Quest Pro 3 (Reality Labs) head-mounted display (HMD). The equipment enables Unity to run at a constant frame rate of over 60 frames per second using the "high quality" display settings of the HMD.

Trial Design and Study Population

Overview

This protocol is for a prospective multicenter randomized clinical trial, which began in March 2025 and is expected to end in November 2025. This protocol outlines our plan to assess the knowledge and skill enhancement of a pilot intervention across three centers: Hasanuddin University (Makassar, Indonesia), Padjajaran University (Bandung, Indonesia), and Universitas Sumatera Utara (Medan, Indonesia). A total of 90 dental students participated in the study (G*Power effect size 0.6, statistical power 85%). All participants enrolled in this study were randomly assigned to either an intervention group (n=15) or a control group (n=15) within each center. We used the block randomization method for the allocation of participants.

Blinding and Calibration of Reviewer

Two independent reviewers (an oral and maxillofacial surgeon) were assigned to evaluate and score each participant's pretest and posttest sheets (Multimedia Appendix 1). Before data collection, the assessors underwent a calibration session to standardize the answer key for the multiple-choice questions (MCQs) and ensure consistent scoring. During the study, the assessors were blinded to the participants' identities and allocation status, as they did not have access to names or group assignments. A final score for each participant was calculated.

Additionally, the reviewer will assess the participants' training videos, focusing on training time completion, in-app lag or confusion, and skipped steps, to evaluate participants' performance during training.

Informed Consent

Before participating in this study, the research assistant explained the trial flow and procedures for both the IR-based training and the conventional training. All participants will receive a brief introduction to the study and will have the opportunity to ask questions about the study procedures. After the participants provide their written informed consent (Multimedia Appendix 2), their basic health status will be recorded (Multimedia Appendix 3). Participants who are unable to give consent will be excluded from the study.

Inclusion Criteria

Participants will be enrolled from the Universitas Sumatera Utara, Hasanuddin University, and Padjajaran University. Eligible participants must be 20 years or older and be currently enrolled in their third year of dental school or have completed

a minimum of seven semesters. They should have completed tutorials on both the open and closed methods of tooth extraction, possess knowledge of medical technology, and be capable of providing informed consent. Individuals who are unable to engage with virtual content for a minimum duration of 10 minutes while using an HMD will be excluded from participation.

Exclusion Criteria

Individuals who are unable to provide informed consent, possess health complications, display symptoms of cybersickness (eg, dizziness, disorientation, or vomiting) during training sessions, or are unable to complete the training session are excluded from participation. Additional exclusion criteria encompass a history of hallucinations, panic attacks, seizures, phobias (including claustrophobia and acrophobia), or active alcohol or substance abuse.

Intervention Group

Before the intervention, two oral and maxillofacial surgeons from each center will follow a comprehensive meeting held in Hasanuddin University, Makassar, to ensure consistent delivery of the interventions across centers and instructors. In addition, a facility assessment will be reported during the meeting to ensure that each center can deliver the intervention method using the same protocol.

Participants will be given a brief introduction and explanation of the study's purpose. A research assistant will present the informed consent both in writing and verbally. This study has adopted standardized procedures for tooth extraction, using both open and closed methods.

The IR training session will be conducted in a standing position, where participants role-play as dentists. The training session will focus on open and closed dental extraction for the first molar tooth (tooth 46), supervised by two oral and maxillofacial surgeons in each center. For all training sessions, the first 10 minutes will be conducted under direct supervision. Participants will then continue their sessions for the last 40 minutes using in-app assistance (sound, highlighted areas, and arrows) without additional support for the remaining session.

The IR HMD wirelessly streams to an external device and will be used during the first session to monitor the participants' training execution and provide guidance when necessary. Participants were required to complete a full round of training. This procedure included several steps: administering local anesthesia, making an incision and separating the tooth (in open method extraction mode), luxating and extracting the tooth, performing curettage, irrigating the wound, and suturing.

Following the completion of the procedure, participants are presented with the option to either restart the training sessions by selecting the reset button or terminate the session by choosing the exit button located in the menu area.

Control Group

Participants in the control group visited the Department of Oral and Maxillofacial Surgery at their origin center (Hasanuddin University, Padjajaran University, or Universitas Sumatera Utara) to receive a tutorial and hands-on laboratory instructions. Following a 10-minute lecture on the open and closed methods of dental extraction for the first molar tooth (tooth 46), participants will engage in hands-on training where they will extract artificial teeth from a phantom or mannequin, much like in the IR-based instructions. The hands-on training will have a duration of 40 minutes, starting from local anesthesia administration, gingival incision, tooth separation, tooth luxation, extraction, curettage, wound irrigation, and suturing. Tutorial and hands-on training will be guided by two oral and maxillofacial surgeons in each center. The trial flowchart is shown in Figure 1. To ensure a standardized methodology for conducting and reporting the trial, the SPIRIT (Standard Protocol Items for Intervention Trials) guidelines will be followed as shown in Table 1.

Figure 1. Research flowchart. CVEQ: Clinical Virtual Evaluation Questionnaire; INRQ: Immersive Reality Neuroscience Questionnaire; IRTS: Immersive Reality Training System.

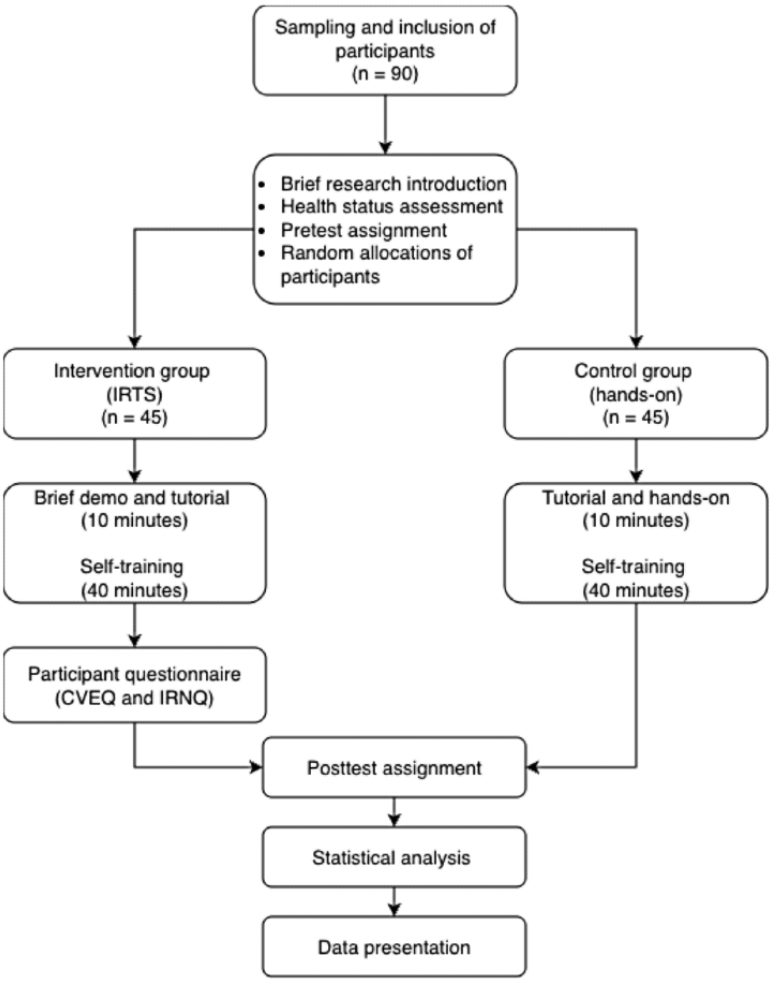

Table 1. SPIRIT (Standard Protocol Items for Intervention Trials) participant timeline.

Timepoint	Enrollment (t_{-1} to t_0)	t_0	Postrandomization (t_1; May 2025)	Closeout (t_x; Nov 2025)
Enrollment				
Eligibility screen	t_{-1}			
Informed consent	t_{-1}			
Baseline assessment (MCQs[a])	✓			
Randomization	✓			
Intervention/comparator				
IRTS[b] for tooth extraction		Tutorial of tooth extraction	✓	✓
Hands-on training		Tutorial of tooth extraction	✓	✓
Assessments				
MCQ questionnaires	✓			✓
Knowledge improvement, posttest scores				✓
Participants' satisfaction with IRTS				✓

[a]MCQ: multiple-choice question.

[b]IRTS: Immersive Reality Training System.

Adverse Events

Participants who report feeling nauseated, dizzy, or disoriented, or having other health problems during a training session, will immediately be excluded from the activity. All such complaints will be recorded as cybersickness, and the occurrence of the condition will be noted for future evaluation.

Data Collection

Participants' Experience and Feedback

This study used two distinct questionnaires to assess the participants' perspectives toward the usability of the Immersive Reality Training System (IRTS) for dental extraction training, which were designed based on previous research [44]. The Clinical Virtual Evaluation Questionnaire is structured to gather participants' feedback on interactive education facilitated through simulator training (Multimedia Appendix 4). This questionnaire assesses three key parameters: experience and reliability (questions 1-9), knowledge (questions 10-14), and side effects (question 15). The questionnaire comprises 15 statements, which respondents assess using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Conversely, the Immersive Reality Neuroscience Questionnaire will assess the system's authenticity, the participants' experiences, and the occurrence of cybersickness (Multimedia Appendix 5). This assessment will concentrate on four principal parameters: user experience (questions 1-5), game mechanism (questions 6-10), in-app assistance (questions 11-15), and IR-induced symptoms and effects (questions 16-20). The questionnaire is composed of 20 questions, which participants will answer using a Likert scale ranging from 1 (extremely poor) to 7 (extremely good). To ensure that the system's quality is deemed suitable for use without causing significant cybersickness, each parameter must meet a minimum threshold (cutoff) score of 25 [45].

Participants' Performance and Knowledge Improvement

To assess the practical skills and knowledge acquired, participants from both the intervention and control groups will be required to complete a pretest prior to the training and a posttest following the training session. The MCQs were administered in accordance with the reference textbook used by the Faculty of Dentistry, as outlined in the dentistry curriculum [46]. The scores ranged from 0 to 100, and the test scores of both groups were subsequently compared. The MCQs are centered on the procedural steps, instrumentation, and guiding principles pertinent to dental extraction. This examination is an established component of the curricula at Hasanuddin University, Padjajaran University, and Universitas Sumatera Utara, aimed at assessing students' practical competencies and theoretical knowledge. Consequently, a comparative analysis test will be used to evaluate the scores obtained from the clinical skill training between these two groups.

Additionally, the performance of participants will be evaluated through recorded video training and will be assessed by an independent reviewer, focusing on training time completion, in-app lag or confusion, and skipped steps. The confidential paper-based data of participants will be securely stored in a locked storage unit at the study site, while electronic data will be maintained in a protected folder on a server at Hasanuddin University, Makassar, Indonesia.

Data Analysis Plan

The data were analyzed using SPSS v.22 (IBM Corp). Both descriptive statistics (frequency, percentage, mean, and SD) and inferential statistics (multivariate ANOVA) were used. A *P* value less than .05 was considered statistically significant.

Ethical Considerations

This study was approved by the Ethics Committee of the Faculty of Dentistry at Hasanuddin University in Makassar, Indonesia, in October 2024 (approval 001/KEPK FKG-RSGMP UH/EE/IX/2024). Written consent was obtained from all participants, and they were also assured that their information would be kept completely confidential. This manuscript is in accordance with the SPIRIT 2025 guidelines (Multimedia Appendix 6) [47].

Results

Study enrollment started in May 2025 and is expected to be completed in November 2025. As of October 2025, we have enrolled 60 participants from two centers (Hasanuddin University, Makassar, and Padjajaran University, Bandung) and will continue recruiting from a third center (Universitas Sumatera Utara, Medan).

The trial was registered in the Indonesian Clinical Research Registry (INA-QES4CC5) on November 18, 2024.

Discussion

Strengths and Limitations

This study uses IR technology to advance the training of dental students in dental extraction methods, allowing them to experience immersive, high-fidelity scenarios that closely resemble actual clinical situations. One of the primary strengths of the IR training program is its incorporation of essential procedures for both open and closed extraction. The adaptation and validation process involves a thorough selection procedure conducted in collaboration with engineering experts. Consequently, the findings will offer both quantitative and qualitative perspectives on the enhancement of participants' abilities. Moreover, the research included dental students from three distinct provinces (West Sumatra, West Java, and South Sulawesi) to provide an in-depth analysis of the potential influence of IR-based training on dental students' skills in performing tooth extractions.

The presence of a control group in this study enables the observation of improvements in dental students. The pre- and posttest MCQs allow not only comparisons within the same group but also evaluation of the IRTS against traditional methods regarding dental students' learning outcomes, thereby strengthening the validity of our findings.

In recognizing the strengths of this study, it is equally crucial to address its limitations. A notable concern is the potential for selection bias, as participants may inherently possess a favorable

disposition toward technology or virtual reality environments. To mitigate this bias, we have meticulously documented the participants' prior interactions with virtual reality technology and incorporated this information into experience distribution tables.

Challenges

One of the primary challenges in this study is the adaptation of the IR environment to align with actual dental extraction procedures. The IR environment differs from conventional simulation in its representation of communication and interaction, as certain elements, such as natural communication with patients and their relatives, may be absent, while others, including nonverbal cues and nuanced interpersonal behaviors, are often not effectively captured within the IR environment. To address this concern, the IRTS has been developed, featuring interactive questions aimed at enhancing students' comprehension of patient diagnoses. Moreover, evaluators face the ongoing challenge of accurately observing and assessing participant behavior in an IR scenario. To consistently and objectively implement the IRTS, it is essential to have a clear and thorough understanding of participant behaviors, both as they occur in real time and through recorded observations. One significant challenge associated with the implementation of IR technologies in dental education is the cost of procurement [48]. However, recent publications indicate that while the initial investment in IR technology may be substantial, it offers the advantage of providing repeatable training without the need for physical materials. Consequently, it can be used in the long term to reduce the costs associated with practical models for tutorials and hands-on training [49]. As the technology becomes more affordable and user-friendly, its applicability in medical and dental training is expected to grow [49].

Future Implications

In addressing certain limitations of the study, future research could investigate the incorporation of more advanced haptic devices and natural language processing to enhance the realism of the IR environment and more comprehensively capture the full spectrum of participant behavior. As IR technology continues to progress, it is imperative to consistently refine the tools used to ensure they remain congruent with the evolving capabilities of the technology.

Acknowledgments

This work was supported by Indonesian Collaborative Research Grant 2024 (Scheme C: 01369/UN4.22/PT.01.03/2024).

The authors attest that there was no use of generative artificial intelligence technology in the generation of text, figures, or other informational content of this manuscript.

Data Availability

The datasets generated or analyzed during this study will be made publicly available after completion of the study and will be available from the corresponding author upon reasonable request.

Authors' Contributions

ES contributed to conceptualization, reviewing and editing, and data curation. MR contributed to data curation, formal analysis, software, and methodology. OAH contributed to project administration, supervision, and visualization. C Stevanie contributed to writing the original draft, reviewing and editing, and methodology. MA contributed to project administration and software. SHK and TF contributed to conceptualization and investigation. PB and C Sukotjo contributed to supervision and validation.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Pretest and posttest multiple-choice questions.
[DOCX File , 21 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Informed consent form.
[PDF File (Adobe PDF File), 143 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Health status form.
[PDF File (Adobe PDF File), 39 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Clinical Virtual Evaluation Questionnaire.

[PDF File (Adobe PDF File), 47 KB-Multimedia Appendix 4]

Multimedia Appendix 5

Immersive Reality Neuroscience Questionnaire.
[PDF File (Adobe PDF File), 59 KB-Multimedia Appendix 5]

Multimedia Appendix 6

SPIRIT 2025 checklist.
[PDF File (Adobe PDF File), 130 KB-Multimedia Appendix 6]

References

1. Reiter AM. Closed and open tooth extraction. In: Reiter AM, Gracis M, editors. BSAVA Manual of Canine and Feline Dentistry and Oral Surgery. London, United Kingdom. British Small Animal Veterinary Association; 2018:304-337.
2. Tonetti MS, Steffen P, Muller-Campanile V, Suvan J, Lang NP. Initial extractions and tooth loss during supportive care in a periodontal population seeking comprehensive care. J Clin Periodontol. Nov 2000;27(11):824-831. [doi: 10.1034/j.1600-051x.2000.027011824.x] [Medline: 11073325]
3. Broers DL, Dubois L, de Lange J, Su N, de Jongh A. Reasons for tooth removal in adults: a systematic review. Int Dent J. Feb 2022;72(1):52-57. [FREE Full text] [doi: 10.1016/j.identj.2021.01.011] [Medline: 33648772]
4. Richards W, Ameen J, Coll AM, Higgs G. Reasons for tooth extraction in four general dental practices in South Wales. Br Dent J. Mar 12, 2005;198(5):275-278. [doi: 10.1038/sj.bdj.4812119] [Medline: 15870746]
5. Rodd HD, Farman M, Albadri S, Mackie IC. Undergraduate experience and self-assessed confidence in paediatric dentistry: comparison of three UK dental schools. Br Dent J. Mar 13, 2010;208(5):221-225. [doi: 10.1038/sj.bdj.2010.207] [Medline: 20228757]
6. Gaballah K, Ali K, Zahra D, Abou Neel E, Ibrahim E. Perceived confidence of dental students and new graduates in performing tooth extractions-an exploratory study. Eur J Dent Educ. Feb 2024;28(1):191-205. [doi: 10.1111/eje.12936] [Medline: 37698270]
7. Dashti M, Londono J, Ghasemi S, Khurshid Z, Khosraviani F, Moghaddasi N, et al. Attitudes, knowledge, and perceptions of dentists and dental students toward artificial intelligence: a systematic review. J Taibah Univ Med Sci. Apr 2024;19(2):327-337. [FREE Full text] [doi: 10.1016/j.jtumed.2023.12.010] [Medline: 38293587]
8. Choi Y, Lee M, Kim J, Park W. Clinical observation using virtual reality for dental education on surgical tooth extraction: a comparative study. BMC Med Educ. Jun 07, 2024;24(1):643. [FREE Full text] [doi: 10.1186/s12909-024-05605-w] [Medline: 38849825]
9. Tanzawa T, Futaki K, Tani C, Hasegawa T, Yamamoto M, Miyazaki T, et al. Introduction of a robot patient into dental education. Eur J Dent Educ. Feb 2012;16(1):e195-e199. [doi: 10.1111/j.1600-0579.2011.00697.x] [Medline: 22251346]
10. Koole S, Van Den Brulle S, Christiaens V, Jacquet W, Cosyn J, De Bruyn H. Competence profiles in undergraduate dental education: a comparison between theory and reality. BMC Oral Health. Jul 11, 2017;17(1):109. [FREE Full text] [doi: 10.1186/s12903-017-0403-4] [Medline: 28693545]
11. McGleenon EL, Morison S. Preparing dental students for independent practice: a scoping review of methods and trends in undergraduate clinical skills teaching in the UK and Ireland. Br Dent J. Jan 2021;230(1):39-45. [FREE Full text] [doi: 10.1038/s41415-020-2505-7] [Medline: 33420457]
12. Ahmad MS, Razak IA, Borromeo GL. Special needs dentistry: perception, attitudes and educational experience of Malaysian dental students. Eur J Dent Educ. Feb 2015;19(1):44-52. [doi: 10.1111/eje.12101] [Medline: 24779684]
13. Ali K, Zahra D, McColl E, Salih V, Tredwin C. Impact of early clinical exposure on the learning experience of undergraduate dental students. Eur J Dent Educ. Feb 2018;22(1):e75-e80. [doi: 10.1111/eje.12260] [Medline: 28160359]
14. McCoy L, Ganesan N, Rajagopalan V, McKell D, Niño DF, Swaim MC. A training needs analysis for AI and generative AI in medical education: perspectives of faculty and students. J Med Educ Curric Dev. 2025;12:23821205251339226. [FREE Full text] [doi: 10.1177/23821205251339226] [Medline: 40376309]
15. Taysi AE, Taysi NM, Sismanoglu S. Evaluation of the efficacy of a simulation model used in oral and maxillofacial surgery education. BMC Med Educ. Mar 19, 2024;24(1):310. [FREE Full text] [doi: 10.1186/s12909-024-05307-3] [Medline: 38504298]
16. Akbay E, Deniş Çeliker H. The effect of immersive reality on science learning: a meta-analysis. Malaysian Online J Educ Technol. Jul 25, 2023;11(3):158-172. [doi: 10.52380/mojet.2023.11.3.304]
17. Adnan K, Fahimullah, Farrukh U, Askari H, Siddiqui S, Jameel RA. AI-enabled virtual reality systems for dental education. Int J Health Sci. Jun 11, 2023;7(S1):1378-1392. [doi: 10.53730/ijhs.v7ns1.14350]
18. Richard E, Tijou A, Richard P, Ferrier J. Multi-modal virtual environments for education with haptic and olfactory feedback. Virtual Reality. Oct 17, 2006;10(3-4):207-225. [doi: 10.1007/s10055-006-0040-8]

19. Carraccio CL, Benson BJ, Nixon LJ, Derstine PL. From the educational bench to the clinical bedside: translating the Dreyfus developmental model to the learning of clinical skills. Acad Med. Aug 2008;83(8):761-767. [doi: 10.1097/ACM.0b013e31817eb632] [Medline: 18667892]
20. Chang J, Bliss L, Angelov N, Glick A. Artificial intelligence-assisted full-mouth radiograph mounting in dental education. J Dent Educ. Jul 2024;88(7):933-939. [doi: 10.1002/jdd.13524] [Medline: 38545660]
21. Hilty DM, Armstrong CM, Edwards-Stewart A, Gentry MT, Luxton DD, Krupinski EA. Sensor, wearable, and remote patient monitoring competencies for clinical care and training: scoping review. J Technol Behav Sci. 2021;6(2):252-277. [FREE Full text] [doi: 10.1007/s41347-020-00190-3] [Medline: 33501372]
22. Ariana A, Amin M, Pakneshan S, Dolan-Evans E, Lam AK. Integration of traditional and e-learning methods to improve learning outcomes for dental students in histopathology. J Dent Educ. Sep 2016;80(9):1140-1148. [Medline: 27587581]
23. Mühling T, Späth I, Backhaus J, Milke N, Oberdörfer S, Meining A, et al. Virtual reality in medical emergencies training: benefits, perceived stress, and learning success. Multimedia Syst. May 12, 2023;29(4):2239-2252. [doi: 10.1007/s00530-023-01102-0]
24. Ricci S, Calandrino A, Borgonovo G, Chirico M, Casadio M. Viewpoint: virtual and augmented reality in basic and advanced life support training. JMIR Serious Games. Mar 23, 2022;10(1):e28595. [FREE Full text] [doi: 10.2196/28595] [Medline: 35319477]
25. Wang N, Yang S, Gao Q, Jin X. Immersive teaching using virtual reality technology to improve ophthalmic surgical skills for medical postgraduate students. Postgrad Med. Jun 2024;136(5):487-495. [doi: 10.1080/00325481.2024.2363171] [Medline: 38819302]
26. Ali M. The role of AI in reshaping medical education: opportunities and challenges. Clin Teach. Apr 2025;22(2):e70040. [doi: 10.1111/tct.70040] [Medline: 39956546]
27. Sriram A, Ramachandran K, Krishnamoorthy S. Artificial intelligence in medical education: transforming learning and practice. Cureus. Mar 2025;17(3):e80852. [doi: 10.7759/cureus.80852] [Medline: 40255837]
28. Popov V, Mateju N, Jeske C, Lewis KO. Metaverse-based simulation: a scoping review of charting medical education over the last two decades in the lens of the 'marvelous medical education machine'. Ann Med. Dec 2024;56(1):2424450. [FREE Full text] [doi: 10.1080/07853890.2024.2424450] [Medline: 39535116]
29. Oyebisi J, Bourguet ML, Stockman T. Work-in-progress—creating immersive learning experiences with generative AI: a case study in dental education. 2024. Presented at: 10th International Conference of the Immersive Learning Research Network; June 10-13, 2024:269-275; Glasgow, Scotland, UK. [doi: 10.56198/u6c0wofmv]
30. Farag A, Hashem D. Impact of the haptic virtual reality simulator on dental students' psychomotor skills in preclinical operative dentistry. Clin Pract. Dec 28, 2021;12(1):17-26. [FREE Full text] [doi: 10.3390/clinpract12010003] [Medline: 35076504]
31. Ben-Gal G, Weiss EI, Gafni N, Ziv A. Testing manual dexterity using a virtual reality simulator: reliability and validity. Eur J Dent Educ. Aug 2013;17(3):138-142. [doi: 10.1111/eje.12023] [Medline: 23815690]
32. Manav EY, Akbiyik SY, Ceylan AB, Çakiroğlu AEY, Tuncer D. Effects of virtual reality and layered tooth model training on manual dexterity in preclinical dental education. BMC Med Educ. Jul 07, 2025;25(1):1020. [FREE Full text] [doi: 10.1186/s12909-025-07622-9] [Medline: 40624647]
33. de Boer IR, Lagerweij MD, Wesselink PR, Vervoorn JM. The effect of variations in force feedback in a virtual reality environment on the performance and satisfaction of dental students. Simul Healthc. Jun 2019;14(3):169-174. [doi: 10.1097/SIH.0000000000000370] [Medline: 31116175]
34. Crogman HT, Cano VD, Pacheco E, Sonawane RB, Boroon R. Virtual reality, augmented reality, and mixed reality in experiential learning: transforming educational paradigms. Education Sci. Feb 28, 2025;15(3):303. [doi: 10.3390/educsci15030303]
35. Goi C. The impact of VR-based learning on student engagement and learning outcomes in higher education. In: Teaching and Learning for a Sustainable Future: Innovative Strategies and Best Practices. Hershey, PA. IGI Global Scientific Publishing; 2024:207-223.
36. Bandiaky ON, Lopez S, Hamon L, Clouet R, Soueidan A, Le Guehennec L. Impact of haptic simulators in preclinical dental education: a systematic review. J Dent Educ. Mar 2024;88(3):366-379. [doi: 10.1002/jdd.13426] [Medline: 38044266]
37. Schwibbe A, Kothe C, Hampe W, Konradt U. Acquisition of dental skills in preclinical technique courses: influence of spatial and manual abilities. Adv Health Sci Educ Theory Pract. Oct 2016;21(4):841-857. [doi: 10.1007/s10459-016-9670-0] [Medline: 26891678]
38. Leung AL, Yeung C, Chu S, Wong AW, Yu OY, Chu C. Use of computer simulation in dental training with special reference to Simodont. Dent J (Basel). Oct 21, 2021;9(11):125. [FREE Full text] [doi: 10.3390/dj9110125] [Medline: 34821589]
39. Nauman AM, Mohiuddin S, Panhwar M, Altaf Y. Exploring the frontier of dental education: a cross-sectional study of VR simulation and manikin-based training at Ziauddin university. BMC Med Educ. May 12, 2025;25(1):695. [FREE Full text] [doi: 10.1186/s12909-025-07221-8] [Medline: 40355867]
40. Im J, Gu J, Bae J, Lee J. Development and user experience of a three-dimensional object-based virtual reality-simulation tool for dental radiography training: a randomized controlled trial. BMC Med Educ. Mar 04, 2025;25(1):334. [FREE Full text] [doi: 10.1186/s12909-024-06623-4] [Medline: 40038644]

41. Bandiaky ON, Loison V, Volteau C, Crétin-Pirolli R, George S, Soueidan A, et al. Benefits of using immersive virtual reality in haptic dental simulation for endodontic access cavity training: a comparative crossover study. Int Endod J. May 12, 2025:1-12. [doi: 10.1111/iej.14252] [Medline: 40353716]
42. Serrano CM, Bakker DR, Zamani M, de Boer IR, Koopman P, Wesselink PR, et al. Virtual reality and haptics in dental education: implementation progress and lessons learned after a decade. Eur J Dent Educ. Nov 2023;27(4):833-840. [doi: 10.1111/eje.12873] [Medline: 36367342]
43. Singh V, Vidya B, Jameela R, Bipinchandra L, Bordoloi P, Srivastav M. The impact of virtual reality-based simulation training on dental students' clinical skills and confidence. J Pharm Bioallied Sci. Dec 2024;16(Suppl 4):S3740-S3742. [doi: 10.4103/jpbs.jpbs_1218_24] [Medline: 39926724]
44. Stevanie C, Ariestiana YY, Anshar M, Sukotjo C, Boffano P, Forouzanfar T, et al. Immersive reality surgical training for Le Fort I orthognathic surgery: initial results of a randomized feasibility study. J Craniomaxillofac Surg. Jul 2025;53(7):1009-1017. [doi: 10.1016/j.jcms.2025.03.014] [Medline: 40189948]
45. Wan T, Liu K, Li B, Wang X. Validity of an immersive virtual reality training system for orthognathic surgical education. Front Pediatr. 2023;11:1133456. [FREE Full text] [doi: 10.3389/fped.2023.1133456] [Medline: 37033170]
46. Hupp JR, Ellis III E, Tucker MR. Principles of Routine Exodontia. In: Contemporary Oral and Maxillofacial Surgery. Amsterdam, Netherlands. Elsevier; 2019:116-132.
47. Hróbjartsson A, Boutron I, Hopewell S, Moher D, Schulz KF, Collins GS, et al. SPIRIT 2025 explanation and elaboration: updated guideline for protocols of randomised trials. BMJ. Apr 28, 2025;389:e081660. [FREE Full text] [doi: 10.1136/bmj-2024-081660] [Medline: 40294956]
48. Akhtar MH, Anderson MT, Cochrane T. Implementing augmented reality and virtual reality for authentic healthcare education: technology enhanced healthcare education for low resource settings with a focus on Australasia. Pacific J Technol Enhanced Learning. Apr 14, 2024;6(1):2-3. [doi: 10.24135/pjtel.v6i1.177]
49. Mansoory MS, Azizi SM, Mirhosseini F, Yousefi D, Moradpoor H. A study to investigate the effectiveness of the application of virtual reality technology in dental education. BMC Med Educ. Jun 15, 2022;22(1):457. [FREE Full text] [doi: 10.1186/s12909-022-03543-z] [Medline: 35705982]

Abbreviations

HMD: head-mounted display
IR: immersive reality
IRTS: Immersive Reality Training System
MCQ: multiple-choice question
SPIRIT: Standard Protocol Items for Intervention Trials

Edited by J Sarvestan; submitted 27.Mar.2025; peer-reviewed by OS Huhtela; comments to author 06.Jun.2025; accepted 17.Oct.2025; published 05.Nov.2025

Please cite as:
Sjamsudin E, Ruslin M, Hanafiah OA, Stevanie C, Hastuti Kurniawan S, Anshar M, Boffano P, Forouzanfar T, Sukotjo C
Immersive Reality–Based Training Simulator for Dental Extraction: Protocol for a Randomized Pilot Trial
JMIR Res Protoc 2025;14:e74978
URL: https://www.researchprotocols.org/2025/1/e74978
doi: 10.2196/74978
PMID: