NHS
Health Education England

Literature Search Results: Innovative technologies in dentistry education

Research question or topic: Evidence review on the use of emerging innovative technologies (Virtual Reality, Extended Reality and Augmented Reality) and simulation in the delivery of dentistry education (theory and practice)
Name of person/ team requesting search: Henrietta Mbeah Bankas (Head of Blended Learning and Digital Literacy Workstream Lead)
Completed by: HEE Knowledge Management Team (Jo McCrossan)
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Please acknowledge this work in any resulting paper or presentation as: Literature Search: Innovative technologies in dentistry education. Jo McCrossan. (30/03/2021). UK: Health Education England Knowledge Management Team

Contents

Search comments

Due to the developing nature of the topic and the volume of available evidence, the search focused on literature published since 2017 to ensure that the most current and relevant results were included.

Complete numbered list of results with links

Specific tools, techniques, applications, etc.

Number	Citation	Abstract/ key themes
1	An immersive educational tool for dental implant placement: A study on user acceptance Ezequiel Roberto Zorzal International journal of medical informatics; Feb 2021; vol. 146; p. 104342 *Abstract only**	• A Virtual Reality system to assist in learning implant placement. • Improves visualization and representation of oral anatomy. • Implants can be placed virtually into their ideal positions related to the planned restorations. • Free-hand interaction provides additional degrees of freedom and valuable geometrical information. • A study on user acceptance with dentistry professionals.
2	Application of augmented reality to transform cellphones into flashcards N. Sharmin, et al. Journal of Dental Education; Feb 2021; vol. 85 (no. 2); p. 244 *Abstract only**	[Abstract] We have used AR to develop an application, called Dental AR that allows students to use their smartphones as flashcards. The application was developed using Unity 3D and Vuforia SDK, which requires the identification of target images. Once a target image is identified, it can be replaced by any other digital output, i.e. 2D image, 3D models or videos. The application detects target images and replaces the target image with a predefined annotated histology image. We believe that the use of the AR application will allow students to study, learn, and perform confidence-based repetition to better understand the complexities of oral histology.
3	Virtual reality program of dental implant surgery: Student perception S. Schreiber, et al. Journal of Dental Education; Feb 2021; vol. 85 (no. 2); p. 243-244	[Abstract] In this study, the Oculus device was used as a platform for an implant placement simulation program designed by our team. Qualitative analysis of this study suggests that the use of virtual reality has potential to be used as a supplemental resource to enhance student learning of specific topics. Additionally, the students have a positive outlook for using virtual reality as a

	*Abstract only**	resource in dental education. They are hopeful to use it in the future for particular topics and subjects such as endodontics, station exams, and emergency clinical situations.
4	3D Printed Teeth with Included Veneer Preparation Guide C. Höhne, et al. Journal of prosthodontics: official journal of the American College of Prosthodontists; Jan 2021; vol. 30 (no. 1); p. 51-56 *Athens log in required**	The study showed that the printed tooth made it possible for students to learn the correct veneer preparation more easily with improved self-education. The students mentioned a possible benefit especially for beginners of the prosthodontic course. The printed tooth can be produced economically and in a short time. It is conceivable to train several forms of preparation with this method. Therefore, crowns, inlays or adhesive bridges etc. might be exercised with the printed tooth.
5	Haptic Rendering of Diverse Tool-Tissue Contact Constraints During Dental Implantation Procedures X. Zhao, et al. Frontiers in robotics and AI; 2020; vol. 7; p. 35 *Athens log in required**	Motor skill learning of dental implantation surgery is difficult for novices because it involves fine manipulation of different dental tools to fulfill a strictly pre-defined procedure. Haptics-enabled virtual reality training systems provide a promising tool for surgical skill learning. In this paper, we introduce a haptic rendering algorithm for simulating diverse tool-tissue contact constraints during dental implantation. […] To achieve the simulation of the complete implant procedures, the realistic simulation of the constrained movement of different implant tools and natural switching between the free motion on the surface and the constrained motion within the preparation bed are fundamental requirements. In this paper, we propose a state switching framework to seamless switch between the free motion state and the constrained motion state. Free motion on the surface can be simulated through the previous proposed virtual coupling method. And the virtual constraint method is built up to render the constrained motion, which shows efficiency in adapting to different kinds of constraint forms during the procedures of sliding, pulling, screwing, and perforating.
6	Making use of three-dimensional models of teeth, manufactured by stereolithographic technology, in practical teaching of endodontics P. Kustra, et al.	[Abstract] Making use of 3D printed teeth models in teaching students offers an innovative approach. The mistakes made by the students at the access cavity stage were assessed with the aid of 3D models, and their overall, hands‐on learning progress was evaluated.

	European Journal of Dental Education; 2020 *Abstract only**	Thanks to perfect representation of teeth anatomy; making use of 3D models in the teaching of endodontics may well be recommended as holding substantial potential in improving overall quality of training at the pre‐clinical stage, with a view to appreciably reducing overall risk of encountering complications during the actual clinical work.
7	Automatic Evaluation of Crown Preparation Using Image Processing Techniques: A Substitute to Faculty Scoring in Dental Education B. Tahani Journal of Medical Signals and Sensors; 2020; vol. 10 (no. 4); p. 239-248 *Athens log in required**	In this research, a new package, including software and its prerequisite instruments, was proposed to help students in preclinical tooth preparation. For this purpose, images were taken from artificial teeth in different angles and directions before and after crown preparation and then were analyzed by the proposed methods to evaluate the quality and quantity of crown preparation. The proposed tooth image processing method had image registration, ROI segmentation, transformation to HSV color space, edge detection, morphology operation, and contour extraction abilities, which computed the amount and angle of crown preparation. Applying the proposed platform to a local tooth dataset showed a mean absolute error of 7.17 and a mean IOU of 0.89 in comparison to gold standard images segmented by the experts. Our method of evaluation seems totally a convenient aid to dental students to evaluate their work. However, before the application of this method as a part of dental education, the accuracy and validity of the outcomes should be tested against the faculty grading, a situation happening routinely in dental schools.
8	Exploring the Presence of Core Skills for Surgical Practice Through Simulation Ahmed Mohammed Balkhoyor, et al. Journal of Surgical Education; 2020 *Abstract only**	**Design, setting & participants** We used a high-fidelity virtual reality dental simulator and a laparoscopic box simulator to record the performance of 3 different groups. The groups comprised dentists, laparoscopic surgeons, and psychologists (each group n = 19). **Results** The results revealed a specialization of performance, with laparoscopic surgeons showing the highest performance on the laparoscopic box simulator, while dentists demonstrated the highest skill levels on the virtual reality dental simulator. Importantly, we also found that a transfer learning effect, with laparoscopic surgeons and dentists showing superior performance to the psychologists on both tasks.
9	Immersion and haptic feedback impacts on dental anesthesia technical skills virtual reality training	**Objectives** Administering anesthesia to the inferior alveolar nerve is 1 of the most stressful processes in dental training. Most studies using virtual reality (VR) for dental

	E. Collaço, et al. Journal of dental education; Nov 2020 *Abstract only**	training have used non‐immersive technologies. The purpose of this work is to assess the impact of immersive technologies on skills training. **Results** Groups receiving immersive preceptorship and/or immersive training showed more accuracy and confidence in administering the anesthesia. Participants perceived a high sense of realism with the haptic feedback when handling the syringe. The machine learning method was validated, with an accuracy of 84%, as a good classifier to assess a student's needle insertion point performance. **Conclusions** The immersive VR simulator allows the practice of the inferior alveolar nerve block under near real conditions and with immediate feedback to the dental student with respect to the needle insertion point. This machine learning based automatic evaluation provides a method to improve technical skills, contributing to dental training.
10	Virtual reality: an effective tool for teaching root canal anatomy to undergraduate dental students – a preliminary study M. Reymus, et al. International endodontic journal; Nov 2020; vol. 53 (no. 11); p. 1581-1587 *Athens log in required**	This investigation found that CBCT and VR appear to be equally suitable for training a student to detect all root canals, to determine whether emerging canals are present and to understand the anatomy of the tooth. Two-dimensional radiographs, however, were found to be inferior in these respects. The advantage of three-dimensional over two-dimensional visualization was not unexpected. However, the study suggests that using VR is not necessarily an improvement compared to CBCT when identifying tooth anatomy. […] Although the results presented in this study favour the use of three-dimensional imaging over conventional radiographs from a didactic point of view, one must emphasize that such an approach must not prohibit the inclusion of interpreting two-dimensional radiographs from the university curriculum. Conventional radiographs are still the most frequently used initial method for diagnosing periapical pathosis. Consequently, dental students must learn to interpret such imaging astutely to provide the best care and treatment possible.
11	Introduction of a new teaching concept for crown preparation with 3D printed teeth C. Höhne, et al.	The feasibility of this teaching concept was confirmed, and the workflow was cost‐effective for the production of the teeth. With the printed teeth, the students had the possibility to learn a correct crown preparation with a standardised tooth with internal preparation. The printed tooth enabled the students on the one hand to control the crown preparation directly on their own and on the other supported the self‐education and learning. The results of the

	European journal of dental education: official journal of the Association for Dental Education in Europe; Aug 2020; vol. 24 (no. 3); p. 526-534 *Athens log in required**	questionnaire showed the great interest of the students in the printed tooth model. The students rated the printed tooth model as significantly better than the standard model tooth. The expert group confirmed the usefulness of this method in their evaluation. The training effect with the printed tooth was significantly better than the standard model tooth in all categories. These were the adequate substance removal, direction of the preparation, correct conicity, preparation margin and smooth surface.
12	Evaluation of HoloHuman augmented reality application as a novel educational tool in dentistry S. Zafar, et al. European journal of dental education: official journal of the Association for Dental Education in Europe; May 2020; vol. 24 (no. 2); p. 259-265 *Abstract only**	This study suggested that the use of AR offers an additional mean of dental anatomy training; however, it cannot be used as a replacement for traditional modes of cadaver anatomy training. AR has the potential to be used as an adjunct tool in the learning of dental head and neck anatomy as it has demonstrated increased student engagement and enjoyment; however, limitations with the device still remain.
13	Contribution of Haptic Simulation to Analogic Training Environment in Restorative Dentistry M. Vincent, et al. Journal of dental education; Mar 2020; vol. 84 (no. 3); p. 367-376 *Abstract only**	[Abstract] The aim of this study was to evaluate the contribution of virtual reality to the conventional analogic training environment and show the complementarity of conventional techniques and virtual reality in the learning of dental students […] The simulator ‐ trained group (group 1) had similar results to the plastic analogue ‐ trained group (group 2) in the final test on a plastic analogue tooth. In this study, virtual reality allowed an assessment based on objective criteria and reduced the subjectivity of evaluations conducted on plastic analogue teeth. Considering the saving of supervision and teaching time as well as the material gain offered by virtual reality, the learning methods of haptic simulators are educational options that should be considered by dental educators.
14	Evaluation of the introduction of a dental virtual simulator on the performance of undergraduate dental students in the pre-clinical operative dentistry course S. Murbay, et al.	The aim of this study was to evaluate the performance of undergraduate dental students with the introduction of the Moog Simodont dental trainer (VR) within the pre-clinical curriculum in the direct restoration module of the operative dentistry course using manual and digital methods.

	European journal of dental education: official journal of the Association for Dental Education in Europe; Feb 2020; vol. 24 (no. 1); p. 5-16 *Abstract only**	The use of the Moog Simodont dental trainer (VR) significantly improved the satisfactory performance of students. The virtual reality simulator may be a valuable adjunct in the undergraduate direct restorations course and for remedial student.
15	Measurement and prediction of drilling force in fresh human cadaver mandibles: A pilot study Y. Dedong, et al. Clinical implant dentistry and related research; Feb 2020; vol. 22 (no. 1); p. 4-12 *Abstract only**	**Background** Bone drilling is a vital procedure in implant surgery and dental implant training systems based on virtual reality technology. **Purpose** Predict and update drilling force in real time based on a virtual dental implant training system and lay the foundation for realizing force feedback in dental implant training instruments. **Conclusion** The experimental data were confirmed to be scientific for the predicted models of drilling force.
16	Virtual articulators in prosthodontics - Review K. Hasan, et al. Drug Invention Today; 2019; vol. 11 (no. 7); p. 1603-1606 *Athens log in required**	The virtual reality technology has opened the door for all the dentists toward successful diagnosis and treatment planning and also for students to understand the advanced technology which is used in dentistry with virtual articulators. The virtual articulator is a precise software tool dealing with the functional aspects of occlusion along with CAD/CAM systems which substitutes mechanical articulators and hence avoiding errors and minimizing corrections. The concept of virtual articulator will change conventional ways of production and communication in dentistry and begin to replace the mechanical tools. **Advantages** • Dynamic visualization of the occlusal surface is possible using virtual articulator. • The clinician can visualize the teeth surface occlusion for contact points and prematurities leading to proper information for the diagnosis. **Disadvantage** • A record has to be made for each patient, which is certainly not practicable for every clinician.

17	The Effect of Variations in Force Feedback in a Virtual Reality Environment on the Performance and Satisfaction of Dental Students I. R. de Boer, et al.	The aim of this study was to investigate the transfer of skills between various levels of force feedback (FFB) using the Simodont dental trainer (Moog, Nieuw-Vennep, the Netherlands). Students practiced a manual dexterity exercise in a virtual reality environment at a standard level of FFB and then were tested at the standard and an altered level of FFB. In addition, the students' satisfaction with the training exercise was evaluated. This study showed that it is possible for (novice) students to acquire a manual dexterity skill at one level of FFB and transfer this skill to another level of FFB in which they have never previously practiced. Therefore, the amount of FFB received from the VRE might be of less importance once a skill is mastered. Results of the questionnaire showed that students noticed when they received different levels of FFB during their test, but the majority did not experience this as more difficult, meaning that subjectively, they felt confident enough to handle the different levels of FFB. Further research that repeats this study with experienced dentists is needed to investigate whether the skills of clinically competent people may be reproduced in the virtual world, thus showing a transfer of skills from reality to VR, especially because for learning, it may not be necessary to have the exact FFB as in reality, though it might be necessary for acceptation of a VRE during implementation in a dental curriculum.
18	Effectiveness of Augmented Reality Mobile Simulator in Teaching Local Anesthesia of Inferior Alveolar Nerve Block R. Mladenovic, et al. Journal of dental education; Apr 2019; vol. 83 (no. 4); p. 423-428 *Abstract only**	The aim of this study was to evaluate the effectiveness of a mobile augmented reality simulator for local anesthesia training with dental students who are administering inferior alveolar nerve block (IANB) for the first time […] The experimental group had a higher average score and/or a more limited range of responses on each item of the questionnaire than the control group. The average time for performing IANB in the experimental group was 50.0±14.3 seconds, while the control group's average was 68.4±25.5 seconds. In addition, the group that used the augmented reality simulator had an anesthesia success rate of 90.9% compared to 73.7% for the control group. Students in both groups had a statistically significant increase in heart rate while performing anesthesia. Overall, the students who used the mobile simulator in addition to their education in augmented reality carried out anesthetic procedures for IANB in a shorter period of time and had greater success than the students who used only the conventional educational methods.

19	Introduction of integrated dental training jaw models and rubric criteria T. Tenkumo, et al. European journal of dental education : official journal of the Association for Dental Education in Europe; Feb 2019; vol. 23 (no. 1); p. e17 *Abstract only**	**Objective** The objective of the present study was to evaluate the effectiveness of introducing integrated jaw models, rubric criteria and homework tasks to a total clinical simulation training course to improve the clinical competence of preclinical dental students. **Methods** A total simulation training course, which involved six clinical dentistry departments, was held for 110 preclinical students in 2014 and 2015. We prepared integrated jaw models having several morbidities along with corresponding medical information and homework tasks. The students formulated diagnoses and devised treatment plans before performing dental treatment on the mannequin under the direction of instructors from the respective clinical departments. Their performance was assessed by both students and instructors using the rubric criteria. **Results** Based on quantitative evaluations, the introduction of integrated jaw models appeared to improve the students' ability to formulate diagnoses and devise dental treatment plans and to understand the respective clinical dentistry disciplines. The rubric criteria provided immediate feedback for the students. Based on a comparison of rubric scores, students tended to significantly underestimate their own performance compared with instructors. Moreover, the introduction of homework tasks improved student seriousness.
20	Effectiveness of the Multilayered Caries Model and Visuo-tactile Virtual Reality Simulator for Minimally Invasive Caries Removal: A Randomized Controlled Trial A. P. Dwisaptarini, et al. Operative Dentistry; 2018; vol. 43 (no. 3) *Abstract only**	**Abstract** This work presents the multilayered caries model with a visuo-tactile virtual reality simulator and a randomized controlled trial protocol to determine the effectiveness of the simulator in training for minimally invasive caries removal. A three-dimensional, multilayered caries model was reconstructed from 10 micro-computed tomography (CT) images of deeply carious extracted human teeth before and after caries removal. The full grey scale 0-255 yielded a median grey scale value of 0-9, 10-18, 19-25, 26-52, and 53-80 regarding dental pulp, infected carious dentin, affected carious dentin, normal dentin, and normal enamel, respectively. The simulator was connected to two haptic devices for a handpiece and mouth mirror. The visuo-tactile feedback during the operation

		varied depending on the grey scale. Sixth-year dental students underwent a pretraining assessment of caries removal on extracted teeth. The students were then randomly assigned to train on either the simulator (n=16) or conventional extracted teeth (n=16) for 3 days, after which the assessment was repeated. The posttraining performance of caries removal improved compared with pretraining in both groups (Wilcoxon, p<0.05). The equivalence test for proportional differences (two 1-sided t-tests) with a 0.2 margin confirmed that the participants in both groups had identical posttraining performance scores (95% CI=0.92, 1; p=0.00). In conclusion, training on the micro-CT multilayered caries model with the visuo-tactile virtual reality simulator and conventional extracted tooth had equivalent effects on improving performance of minimally invasive caries removal.
21	Innovation in dental education: The "On-the-Fly" approach to simultaneous development, implementation and evidence collection I. R. de Boer, et al. European Journal of Dental Education; 2018 *Abstract only**	**Introduction** This study outlines an approach for education innovation and addresses the ambivalence between evidence-based and non-evidence-based conditions. The "on-the-fly" approach was described as involving implementation during the development of an innovation for dental education. **Materials and Methods** The process of designing and implementing cutting-edge technology of the MOOG Simodont Dental Trainer (DT) whilst systematically collecting evidence illustrates the "on-the-fly" approach. **Results** Using the "on-the-fly" approach for developing, implementing and collecting evidence simultaneously in an academic environment appears feasible in serving both the professionals, users and developers and system designers. During the implementation of the new technology, growing evidence stepwise strengthened its position; therefore, showing stakeholders that evidence was used to improve the technology seemed to support and increase acceptance of the new technology. **Conclusions** When pioneering an innovative technology in a specialty field, the development stage often precedes evidence for its effectiveness. Consciously choosing the "on-the-fly" approach clarifies to stakeholders in advance about the lack of evidence in an innovation and the need of their support to collect such evidence for improvement and in order to facilitate implementation.

22	Simulation training for medical emergencies in the dental setting using an inexpensive software application N. Kishimoto, et al. European journal of dental education : official journal of the Association for Dental Education in Europe; Aug 2018; vol. 22 (no. 3); p. e350 *Abstract only**	**Introduction** Every dental provider needs to be educated about medical emergencies to provide safe dental care. Simulation training is available with simulators such as advanced life support manikins and robot patients. However, the purchase and development costs of these simulators are high. We have developed a simulation training course on medical emergencies using an inexpensive software application. The purpose of this study was to evaluate the educational effectiveness of this course. **Conclusions** This simulation course improved participants' ability to diagnose and treat medical emergencies and improved their confidence. This course can be offered inexpensively using a software application.
23	Capturing differences in dental training using a virtual reality simulator Israa Mirghani, et al. European journal of dental education: official journal of the Association for Dental Education in Europe; Feb 2018; vol. 22 (no. 1); p. 67-71 *Athens log in required**	The Simodont has shown sensitivity to performance differences between novice and experienced students. Thus, the Simodont has potential in stratifying different 13 levels of dental students performance (with the performance metrics that it automatically generates). The Simodont has shown convergent validity, suggesting it has good potential for measuring dental performance and educating students. Nevertheless, a variety of tasks of differing difficulty are likely to be required for fine graded discrimination (where easier tasks may have discriminatory ability at the novice end of the spectrum and vice versa).
24	Automated outcome scoring in a virtual reality simulator for endodontic surgery Myat SuYin, et al. Computer methods and programs in biomedicine; Jan 2018; vol. 153; p. 53-59 *Abstract only**	• Numerous VR simulators have been developed as a means of addressing limitations of the traditional apprenticeship approach to dental surgical skill training. • Most existing simulators support intra- and extra-coronal procedures such as caries removal. • We address the problem of automated outcome assessment for endodontic surgery. • Outcome assessment is an essential component in providing formative feedback, which requires assessing the outcome, relating it to the procedure, and communicating in a language natural to dental students. • This paper takes a first step toward automated generation of such comprehensive feedback.

		• Detailed scores are transformed into the standard scoring language used by dental schools. • Results from the evaluation of our system with expert endodontists show a high degree of agreement with expert scores.
25	Virtual Reality simulator for dental anesthesia training in the inferior alveolar nerve block. C. G. Corrêa, et al. Journal of applied oral science: revista FOB; 2017; vol. 25 (no. 4); p. 357-366 *Athens log in required**	The growth in the use of VR simulators may be related to the benefits provided by them, such as: they reduce risks, preventing discomfort and complications that can be detrimental to the patients' health, they increase the safety of the students, who often practice on their own colleagues or patients, and they allow automated performance evaluations. Moreover, these simulators use different training levels, with varying situations and difficulty levels. They can minimize or eliminate infrastructure and maintenance costs of physical laboratories, which include cadavers or animals. The VR-based simulators have led to realistic trainings, offering advantages over the use of cadavers and animals. Although cadavers offer a physical presence, they are physiologically different from living organisms. Animals have anatomical differences in relation to human. Additionally, the use of both (cadavers and animals) in training situations involves ethical issues that must be properly considered, as well as the difficulties to obtain these materials for training. In the virtual training context, realism is very important. Most VR simulators have limitations to reproduce reality accurately. The haptic device used in this study has certain limitations, especially to simulate the IANB using the direct technique. […] The simulator was considered thoroughly satisfactory for the anesthesia training, considering the needle insertion task, which includes the correct insertion point and depth, as well as the perception of the tissues' resistances during the insertion. Although this research is not finished and many points will be improved in the simulator, volunteers stated that it can be used as a complementary tool in the IANB teaching procedure.
26	Feedback and motor skill acquisition using a haptic dental simulator Loulwa M. Al-Saud, et al. European journal of dental education: official journal of the Association for	The learning of basic manual dexterity skills was accelerated when participants were provided with haptic device feedback in conjunction with an experienced dental instructor, relative to groups with access to the device only or instructor only feedback. This was particularly beneficial for the retention of learned skills. There was an overall performance improvement for all groups at the end of the

	Dental Education in Europe; Nov 2017; vol. 21 (no. 4); p. 240-247 *Athens log in required**	experiment (retention phase), which was evidenced by lower error scores as well as comparable time for task performance (DT). These data indicate that integration of VR into a dental curriculum needs consideration in order to maximise VR's potential utility in motor skill learning and to complement existing simulation techniques. Future research should address the feasibility of integrating multimodal simulation and examine whether combining the best features of virtual reality-based and traditional non-computerized simulation approaches can enhance motor skill acquisition. Furthermore, the long-term effects of VR delivered training are relatively unknown, as are individual differences (e.g., the influence of different levels of stereoacuity) and these issues require further exploration.
27	Utilising an innovative digital software to grade pre-clinical crown preparation exercise E. T. Kateeb, et al. European journal of dental education : official journal of the Association for Dental Education in Europe; Nov 2017; vol. 21 (no. 4); p. 220-227 *Abstract only**	**Background** Accurate assessment of dental students' pre-clinical work is the most critical component of the dental education process. Thus, this study came to investigate the effectiveness of using technology in students' pre-clinical work evaluation; by comparing grades generated from a digital assessment software of a prepared tooth and a traditional visual inspection carried out by four calibrated faculty members. **Conclusions** This study demonstrates that the digital grading system used in this study can reliably scan and compare students' tooth preparations to a known gold standard. Results of this study suggests that using digital grading will preclude the variability and the subjectivity that usually result from the traditional visual inspection grading.
28	Computerized Virtual Reality Simulation in Preclinical Dentistry: Can a Computerized Simulator Replace the Conventional Phantom Heads and Human Instruction? A. Plessas Simulation in healthcare: journal of the Society for Simulation in Healthcare; Oct 2017; vol. 12 (no. 5); p. 332-338	The existing body of evidence suggests that combining and alternating the traditional and pioneering simulation methods and feedback may be of benefit to the learners. However, there is insufficient evidence to advise for or against the use of computerized virtual reality simulators as a replacement of the traditional phantom heads and human instruction. Virtual reality simulation may enable a better understanding among learners in a more diverse learning environment and augment rather than replace existing teaching methods that work well such as faculty instruction and feedback. Incorporating such a technology in the dental curriculum can add a substantial expense nevertheless to a dental faculty's budget. Well-designed and adequately powered long-term prospective

	*Athens log in required**	studies exploring matters of student performance, learning outcomes, and cost effectiveness are warranted.
29	Evaluation of a Vibrotactile Simulator for Dental Caries Detection K. J. Kuchenbecker, et al. Simulation in healthcare: journal of the Society for Simulation in Healthcare; Jun 2017; vol. 12 (no. 3); p. 148-156 *Abstract only**	**Introduction** Developed to educate dental students in caries detection, the VerroTeach simulator allows dental faculty to share, record, and replay the tactile vibrations felt through a dental hand instrument. We assessed this simulation approach by asking experienced dental educators to evaluate the system's real-time and video playback modes. **Results** Dental educators rated caries detection as significantly more difficult for students than experienced dentists (P < 0.0001), and they rated tactile feedback as a highly important source of information for this judgment. Subjects highly rated the realism of both real-time mode and playback mode. Experienced dentists performed well on the simulator, answering most questions correctly. Interestingly, nonpracticing dentists performed significantly worse than practicing dentists on the caries judgment questions (P = 0.003). Finally, subjects strongly recommended the system for training dental students. **Conclusions** These positive results indicate that sharing, recording, and replaying instrument vibrations may be beneficial for teaching caries detection to dental students.
30	The need for virtual reality simulators in dental education: A review Author links open overlay panel E. Roy, et al. The Saudi dental journal; Apr 2017; vol. 29 (no. 2); p. 41-47 *Athens log in required**	This article, while providing an overview of the virtual reality dental simulators, also looks at the link between virtual reality simulation and current pedagogical knowledge. Current literature indicates that virtual reality dental simulators are valuable educational tools that could augment the current traditional teaching methods. Development of a validated single scoring system to the test the improvement in skills achieved across the various available simulators could help assess benefits of each simulator within the pre-clinical dental education framework. Rapid advances in hardware and software technology should further allow for a better virtual reality experience and adaptation of this technology as an essential part of modern education.
31	Validation of a Novel Cognitive Simulator for Orbital Floor Reconstruction Renata Khelemsky, et al.	The present study investigated the validity of a novel cognitive VR simulator called Touch Surgery for a core maxillofacial surgical procedure: orbital floor reconstruction (OFR). Thirty-nine novices and 10 experts who were naïve to Touch Surgery were recruited for the study. Experts outperformed novices on phases 1 and 2 of the OFR module (P < .001), which provided the measurement

	Journal of oral and maxillofacial surgery: official journal of the American Association of Oral and Maxillofacial Surgeons; Apr 2017; vol. 75 (no. 4); p. 775-785 *Abstract only**	of construct validation. Responses to the questionnaire items used to assess face validity were favorable from the 2 groups. Positive questionnaire responses also were recorded from experts alone on items assessing the content validity for the module. Participant age and gender were not relevant predictors of performance scores.

Impact, reviews, and reports

Number	Citation	Abstract/ key themes
32	Formative feedback generation in a VR-based dental surgical skill training simulator Myat Su Yin, et al. Journal of biomedical informatics; Feb 2021; vol. 114; p. 103659 *Abstract only**	• Existing VR dental skill training simulators do not fully support for formative feedback. • Our approach is to objectively assess surgical skills and generate formative feedback. • Performance improvements are observed in participants trained with formative feedback. • Our approach could increase the teaching effectiveness of existing training simulators.
33	Immersive 3D Educational Contents: A Technical Note for Dental Educators S. Barour, et al. Healthcare (Basel, Switzerland); Feb 2021; vol. 9 (no. 2) *Athens log in required**	Digital technologies open up the possibility to improve dental education. A proposition is made here to help educators easily prepare 3D files. These procedures open up many applications and possible educational collaborations for dental educators. Further comparisons with current practices will be required to identify and select 3D tools that really improve teaching and learning.
34	Augmented reality in clinical dental training and education Z. Haji, et al. JPMA. The Journal of the Pakistan Medical Association; Jan 2021; vol. 71	[Abstract] Conventional pre-clinical training employed the use of cadavers, but financial, ethical and supervisory constraints have become a major shortcoming. With the adaptation of technology in dentistry, pre-clinical training has now employed simulation. It provides the opportunity for students to develop psychomotor skills for procedures by practising pre-clinical, standardised learning competencies

	*Abstract only**	before they engage in patient-management. Simulation involves computer-aided learning, augmented reality and virtual reality, which are largely taking over pre-clinical teaching. Augmented reality is commonly being employed in maxillofacial, restorative, tooth morphology learning and mastering technique for administering local anaesthesia in dentistry. Virtual reality is being employed particularly in pre-treatment implant planning and dental education for students. Use of haptic technology, like robotics, is also gaining popularity, and facilitates a two-way communication between the user and the environment to better simulate the clinical setting for learning purposes.
35	Edutainment in dental curriculum-A systematic review P. Mehrotra Journal of oral biology and craniofacial research; 2020; vol. 10 (no. 4); p. 417-421 *Athens log in required**	Novelty sparks curiosity and ignites the desire for knowledge, extinguishing all ashes of doubt. Edutainment tools like games, animations and mime are the just the three examples that this study mentioned. It is imperative to acknowledge that utility, beneficence and substantivity lies in the design of such tools. Games, animations and mime mostly correspond to improved understanding, student engagement, student motivation and better test scores. They provide a much desired respite from traditional learning and the ease of availability and accessibility also benefits the scholars. Students too find games, animation and mime, a very entertaining way to learn, and desire them to be used in teaching. Edutainment is highly promising supplemental teaching learning tool with a bright and momentous future ahead. […] Instead of imparting knowledge, edutainment tools may serve as a distraction, obviating students to read from textbook. Such tools drift away from traditional textbook learning, that is said to stimulate robust brain activity, and hamper the art of textbook reading that may affect the in-depth knowledge attained. Therefore, a balance and moderation are the key factors for its success.
36	The impact of scientific technologies and discoveries on oral health globally I. F. Dragan, et al. Journal of Dental Education; 2020; vol. 84 (no. 1); p. 111-116 *Athens log in required**	New dentists of the future need to be educated with in the wider healthcare team, and involved more with general health, its maintenance and disease prevention. New simulations with mixed reality will allow students to interact with virtual patients, formulating diagnoses and surgically intervening when required. These new technologies will allow personalized learning plans with different students progressing at different rates through the program. Reflection and self-feedback can be encouraged with less reliance on expert teachers.

		The potential is limitless, but the cost and speed of developing new technologies working within the legal restraints of some jurisdictions may hinder important technological breakthrough. […] Technology in the healthcare sector has effected, and will continue to effect, massive impacts on nearly all processes and practices. The educational and cultural implications of these changes are so large as to be almost incomprehensible. Thus, it is critical that across the globe, dental educators continue to examine scientific and technology advances and continue to improve the strategies used to incorporate these advances into our instruction. Within the next decade, technology and artificial intelligence or machine learning will impact the digitisation of health care records and the patients' journey through the health care system.16 Big data will streamline the journey from a "patient" to a "person" and continuous recording of data will help stop or at least delay some persons becoming patients. Computerised or digital records will ease the workflow and retrieval of data, increasing productivity and efficiency of healthcare systems. Disease patterns and clusters of diseases within populations will be more easily recognised, predicting epidemics, avoiding preventable deaths, improving quality of life and identifying most effective treatments.
37	COVID-19 Era: Challenges and Solutions in Dental Education Z. Haroon, et al. Journal of the College of Physicians and Surgeons--Pakistan: JCPSP; Oct 2020; vol. 30 (no. 10); p. 129-131 *Athens log in required**	Dental educators have come up with innovative solutions to resume dental education remotely. Different online platforms are being utilised for didactic teaching and learning as well as for students' assessment and examination. Clinical learning has also shifted to virtual learning. Manikins and virtual reality/augmented reality (VR/AR)-based simulation devices along with haptic technology can be very helpful for skills training. However, some sorts of blended learning and virtual curriculum may be incorporated in dental education in the future. […] **Pre-clinical and clinical learning:** Dental education differs from traditional medical education as in this, a dental student has to gain sufficient amount of practical skill to qualify their final examination. Hands-on skill acquisition is the cornerstone in dental training. In the present scenario of lockdown and elective dental care, it is difficult for the students, especially the 3rd and 4th year students, to achieve this milestone.

		Traditionally, many dental schools use manikins and physical typodonts for the first two years of teaching. With the advancement in technology, alternate teaching methods such as haptics, VR/AR-based simulation devices (e.g. Simodont, DentSim, Periosim, etc.) have also been developed. These non-clinical teaching and learning methods are safe and reliable in providing the students with the much-needed achievement of fine-motor skills and manual dexterity. These simulation devices accompanied by haptic technology provide tactile feedback to enable the students feel and touch the virtual teeth. AR/VR technology is an effective supplemental teaching tool, which enables the students to gain clinical experience without being in a clinical environment. But these simulators do not cover all aspects of dentistry, are yet scarce in developing countries and quite expensive. We suggest that these evidence-based methods should be developed and made accessible to a wide number of dental institutions throughout the world. Presently, they do not replace the traditional practical training methods in many dental setups, especially in the developing world. Meanwhile, PBL and virtual-patient-based learning offer great learning material to train students on clinical diagnosis and decision-making.
38	Virtual education: Dental morphologies in a virtual teaching environment Anja Liebermann, & Kurt Erdelt Journal of dental education; Oct 2020; vol. 84 (no. 10); p. 1143-1150 *Abstract only**	34.9% stated that they understand dental morphologies much better, 57.1% better, and 7.9% equally well compared to using the traditional textbook. The students would be willing to spend about 500 euros privately for the VR equipment. The haptic and auditive teaching elements were evaluated more positively than the purely visual ones of the integrated information boards. Learning in the VR dental learning environment showed a high level of acceptance among all students and should be integrated as a fixed element in the dental curriculum. A further development for use independent of time and place is desirable.
39	Computer simulation and virtual reality in undergraduate operative and restorative dental education: A critical review H. M. Nassar, et al. Journal of dental education; Jul 2020; vol. 84 (no. 7); p. 812-829	The primary aim of this review was to synthesize the literature for studies investigating the use of computer simulation (CS) and virtual reality (VR) in undergraduate dental education in operative and restorative dentistry […] CS was efficient in teaching cavity preparation and light curing skills. Feedback and deliberate practice were among the best practices that should be emphasized in order to enhance the efficiency of the CS and VR simulation exercises. The use of CS is effective in teaching operative skills (such as light curing and cavity preparation) reliably; whereas, the use of VR in undergraduate curricula is

	*Abstract only**	debatable. To achieve the maximum benefits of the simulation exercises, emphasis must be given to the timely feedback and deliberate practice approaches.
40	Augmented Reality Application to Develop a Learning Tool for Students: Transforming Cellphones into Flashcards N. Sharmin, et al. Healthcare informatics research; Jul 2020; vol. 26 (no. 3); p. 238-242 *Athens log in required**	We have developed an augmented reality (AR) flashcard application using Unity3D, which requires the user to identify a target image. Once the target image is identified, it can be replaced by any other digital output, i.e., 2D image, 3D models, or videos. We used images of histological sections of oral mucosa, which dentistry students study as a part of an oral biology course. […] This simple application can be tailored according to any teaching needs. Instructors will be able to provide students with sets of practice questions or concepts that are needed for a specific course and its learning outcomes. This mobile AR application is equally suitable for video and animation files. Instructors will be able to incorporate animations and video clips according to their own needs and objectives. Having the AR flashcard application in their phones and iPads, students will be able to study during their free time, while traveling or on their way to school at their own pace and without any internet connection. Students will be able to self-test their knowledge on a given topic, perform confidence-based repetition to memorize and practice, watch incorporated videos and animations to learn, and self-test physiological or any other cellular mechanisms.
41	First experiences with patient-centered training in virtual reality C. M. Serrano Journal of dental education; May 2020; vol. 84 (no. 5); p. 607-614 *Athens log in required**	This article describes the development and first experiences with a patient-centered virtual reality training module (PC-VR) that allows dental care providers to prepare, beforehand and in virtual reality (VR), specific procedures required by their patients. Experiences with this patient-centered practice are described to reflect on its value for clinical training in dentistry. This article provides a general overview of the possibilities and challenges of the implementation PC-VR in dental education. Although concrete effects on trainees' self-confidence and performance are yet to be determined, all participants appreciated the opportunity to explore clinical situations before experiencing them in the context of a real patient.
42	Digital Undergraduate Education in Dentistry: A Systematic Review N. U. Zitzmann, et al.	Digital tools and applications are now widespread in routine dental care. Therefore, this trend towards digitization and ongoing developments must be considered in dental curricula in order to prepare future dentists for their daily

	International journal of environmental research and public health; May 2020; vol. 17 (no. 9) *Athens log in required**	work-life. There is a need to establish generally accepted digital standards of education—at least among the different dental universities within individual countries. Digitalization offers the potential to revolutionize the entire field of dental education. More interactive and intuitive e-learning possibilities will arise that motivate students and provide a stimulating, enjoyable, and meaningful educational experience with convenient access 24 h a day. At present, digital dental education encompasses several areas of teaching interests, including Web-based knowledge transfer and specific technologies such as digital surface mapping, dental simulator motor skills including IOS, and digital radiography. Furthermore, it is assumed that AR/VR-technology will play a dominant role in the future development of dental education.
43	Dentistry, e-health and digitalisation: A critical narrative review of the dental literature on digital technologies with insights from health and technology studies P. Neville, et al. Community Dental Health; Mar 2020; vol. 37 (no. 1); p. 51-58 *Abstract only**	[Abstract] Four themes are identified as characterising the current dental literature on e-health and digitalisation: 1) the impact of digitalisation on dental surgeries, 2) digital technology and practice management, 3) digitalisation beyond the dental surgery and in dentist-patient communication, and 4) digital technology and education. However, gaps remain in our understanding of the impact of digital technology on dental practice, particularly in relation to its ethical considerations. Following the example of the wider medical literature, the review introduces the field of critical digital health studies and identifies areas for future investigation and exploration based on its four characteristics: devices and software, data materialisation, data practices and data mobilities. Conclusion and Clinical significance: Digital technology is changing clinical practice and patient care. Dentistry needs to expand its understanding of how dental apps, digital workflow models and digital health information are transforming and disrupting dental practice in order to anticipate how this digital shift will impact on dentistry. The emerging field of critical digital health studies can signpost ways to improve research and practice on the topic in the future.
44	Effects of dental students' training using immersive virtual reality technology for home dental practice D. Takagi, et al.	The aim of the present study is to prototype virtual reality (VR) teaching material for home dental practice to provide dental students with the chance to observe patients receiving home dental care. The VR teaching material was created before the study, using a patient's home as the medical treatment scene, and practical training was then conducted using this VR teaching material with dental

	Educational Gerontology; Nov 2019; vol. 45 (no. 11); p. 670-680 *Abstract only**	students […] There was a significant increase in student's knowledge confidence and assistance confidence scores (p < .001). Moreover, hierarchical cluster analysis indicated a change in the cluster before and after they watched the VR teaching material. Given that VR teaching material makes it possible to conduct home observation training for a variety of reasons, such as lack of available facilities or patient reservation issues, the findings indicate that VR teaching material can supplement dental students' training in home dental practice.
45	The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery A. Ayoub, et al. BMC oral health; Nov 2019; vol. 19 (no. 1); p. 238 *Athens log in required**	The main application of virtual reality is in implantology and orthognathic surgical. Virtual reality facilitated the restoration of orbital floor following blow out fracture and the planning of mandibular reconstruction following cancer resection […] The technical skills learnt by the trainees on the virtual surgery simulators are limited but expected to transfer into a stressful environment of operating theatre. However, as a surgical procedure is a combination of expert anatomical knowledge, spatial visualisation, judgment and inter-professional teamwork, it is essential to give a holistic learning experience to the trainees. Hence, there is a gap in the modern simulators developed for dentistry and oral and maxillofacial surgery, which needs to be met adequately. Researchers attempted the use of serious games and gamification of simulations to overcome these training obstacles.
46	Innovative Trends in Implant Dentistry Training and Education: A Narrative Review A. S. Ferro, et al. Journal of clinical medicine; Oct 2019; vol. 8 (no. 10) *Athens log in required**	Cost savings and overcoming a shortage of teachers and supporting faculty are often cited as reasons for implementing the use of technology in dental education. Elby et al. describe the need for virtual reality simulators in dental education. They discuss the use of high-fidelity robotic patient models that cough, tongue thrust, shake the neck and secrete saliva in aiding the teaching of medical emergency management in the dental setting. […] Education in implant dentistry will evolve quickly over the next decade as technologies already being used in other industries are incorporated into new and innovative learning models. The merging of technological innovations culminating in "digital dentistry" make the "digital education of digital dentistry" inevitable. Going forward, instead of traditional models of education being used to achieve all educational objectives, now traditional formats that will be ineffective with today's learner will be replaced, where appropriate, with online education, AR, ML, VR, and MR. Of course, an important need in education will still be addressed through one-on-one mentoring and lecture format teaching

		models. However, the restraints of these models will be released through innovative use of new technologies that allow for different, deeper, local and global, near and distant educational experiences.
47	Clinical and academic recommendations for primary dental care prosthodontics R.C. Olley, et al. British Dental Journal; Sep 2019; vol. 227 (no. 6); p. 451-455 *Athens log in required**	**3. How can we use and implement digital technologies in dentistry to best improve oral health?** Among RCTs that do exist, there are also differences in the outcomes, for example, in terms of mechanical and aesthetic advantages of the final prosthesis. Important patient outcomes, including satisfaction, are reported in small non-randomised studies, although these are sometimes not wholly in favour of contemporary over conventional practices, or show little difference on final restoration outcome between techniques. Similarly, systematic reviews on conventional versus digital impressions again suggest caution over adoption of digital technologies due to the lack of well conducted clinical trials. There is a need for closer collaboration between manufacturers, academics and clinicians, in order to keep pace with developments, and research the potential and ongoing contribution of new technologies relevant to improving oral health for patients…
48	Digitally Augmented Learning in Implant Dentistry M. Durham, et al. Oral and maxillofacial surgery clinics of North America; Aug 2019; vol. 31 (no. 3); p. 387-398 *Abstract only**	[Abstract] The economic forces in the dental education industry yield a high cost for a dental degree, yet the financial return for this education yields a small margin above the costs for this degree. Industries with unfavorable return to investment ratios tend to be vulnerable to changes. Productive technologies are emerging that may be useful in improving the return to investment ratios in dental education. Virtual reality and online learning provide productive value that could be useful to the dental education industry. A description and use cases of virtual reality in dental implantology education are provided.
49	Current state of the art in the use of augmented reality in dentistry: a systematic review of the literature M. Farronato, et al. BMC oral health; Jul 2019; vol. 19 (no. 1); p. 135 *Athens log in required**	On the base of literature the current development is still insufficient for full validation process, however independent sources of customized software for augmented reality seems promising to help routinely procedures, complicate or specific interventions, education and learning. Oral and maxillofacial area is predominant, the results in precision are promising, while timing is still very controversial since some authors describe longer preparation time when using augmented reality up to 60 min while others describe a reduced operating time of 50/100%.

50	A scoping review of the use and application of Virtual Reality in Preclinical Dental Education A. Towers, et al. British dental journal; Mar 2019; vol. 226 (no. 5); p. 358-366 *Athens log in required**	This paper provides an important review of the current literature regarding VR simulation for dental education as it has highlighted a significant number of weaknesses and underlying assumptions in the existing literature. The authors recommend a number of areas requiring further investigation: • There are no established educational standards for dental simulators or their associated exercises. • It is unclear how the variable fidelity across simulator systems may impact on skills acquisition. • A number of core operative concepts are under-represented within the simulator environment such as a finger rest and student posture. The way in which this impacts on student development is unclear. • Comparisons between the relative importance of different methods of perceiving 3D depth for simulation-based dental training are not reported in the literature • Further study should explore the value of deliberate practice, which in turn will inform the degree of fidelity and realism that are required from modern simulation systems. • The scoring mechanisms employed by many simulators have not been validated in relation to actual clinical performance, and clinical tutor feedback. • The way in which VR is introduced and integrated into curricula is variable and its impact on student satisfaction and progression is unknown. • The synergy between clinical tutor and simulator-generated feedback must be further explored in order to maximise pedagogic value and efficient utility of resources.
51	Haptic, Physical, and Web-Based Simulators: Are They Underused in Maxillofacial Surgery Training? S. G. Maliha, et al. Journal of oral and maxillofacial surgery: official journal of the American Association of Oral and Maxillofacial Surgeons; Nov 2018; vol. 76 (no. 11); p. 2424	**Purpose** The aim of our review was to identify all digital and mannequin maxillofacial simulators available for education and training, highlight their benefit, and critically assess the evidence in support of these educational resources. **Conclusions** The results of this review suggest that, although seemingly beneficial to the trainee in maxillofacial surgery, simulation in education in this field is an underused commodity because of the significant lack of scientific and validated study designs reported on in the literature thus far. The maxillofacial and

	*Abstract only**	simulation communities would benefit from studies on utility and efficacy with higher levels of evidence.
52	Augmented reality in dentistry: a current perspective Ho-Beom Kwon, et al. Acta odontologica Scandinavica; Oct 2018; vol. 76 (no. 7); p. 497-503 *Abstract only**	Augmentation reality technology offers virtual information in addition to that of the real environment and thus opens new possibilities in various fields. The medical applications of augmentation reality are generally concentrated on surgery types, including neurosurgery, laparoscopic surgery and plastic surgery. Augmentation reality technology is also widely used in medical education and training. In dentistry, oral and maxillofacial surgery is the primary area of use, where dental implant placement and orthognathic surgery are the most frequent applications. Recent technological advancements are enabling new applications of restorative dentistry, orthodontics and endodontics. This review briefly summarizes the history, definitions, features, and components of augmented reality technology and discusses its applications and future perspectives in dentistry.
53	Effectiveness of Immersive Virtual Reality in Surgical Training - A Randomized Control Trial Y. Pulijala, et al. Journal of Oral and Maxillofacial Surgery; May 2018; vol. 76 (no. 5); p. 1065-1072 *Athens log in required**	The main objective of the present study was to evaluate the effect of using VR surgery on the self-confidence and knowledge of surgical residents. Participants in the study group used the VR surgery application on an Oculus Rift with Leap Motion device. The control group participants used similar content in a standard PowerPoint presentation on a laptop. The study group participants showed significantly greater perceived self-confidence levels compared with those in the control group (P =.034; alpha = 0.05). Novices in the first year of their training showed the greatest improvement in their confidence compared with those in their second and third year. […] As commercially available virtual reality and augmented reality experiences are increasingly used for surgical training, a framework to build effective iVR solutions is needed. Our study attempts to address that challenge through a three-step process of co-development, iteration and evaluation among surgical residents. Currently, the head mounted VR devices are expensive and requires computers of high specifications for a satisfactory virtual reality experience. However, these computers are not easily available in University teaching hospitals and NHS. To ensure the global application of these emerging technologies, they should be made more affordable. Once the challenges are met, VR Surgery will provide an alternative way of learning and can reduce the time taken in training surgeons in operating rooms.

54	Simulation and curriculum design: a global survey in dental education S Perry, et al. Australian dental journal; Dec 2017; vol. 62 (no. 4); p. 453-463 *Abstract only**	This survey indicated considerable variation in curriculum structure with regionally-specific preferences being evident in terms of curriculum structure, teaching philosophies and motivation for incorporation of VR haptic simulation into curricula. This study illustrates the need for an improved evidence base on dental simulations to inform curriculum designs and psychomotor skill learning in dentistry.
55	The Effect of New Oral Care Technologies on the Need for Dentists in 2040 P. M. Milgrom, & J. A. Horst Journal of Dental Education; Aug 2017; vol. 81 (no. 8) *Abstract only**	This article addresses changes in technology of oral self-care or professional care that may increase or decrease the demand for dentists by 2040. The focus is on dental caries, periodontitis, and temporomandibular joint disorders (TMD) […] The pipeline of applicable technology is limited. Nevertheless, between now and 2040, emerging technologies will continue to reduce the need for training more dentists, while no technologies are emerging that will significantly increase the need. Technology in dentistry is adopted slowly as is true in other medical specialties. If a breakthrough product did appear, the results of industry-sponsored trials would be viewed sceptically by the profession, and considerable time would be required to establish the applicability of the findings to the broader population. Greater integration of dentistry into preventive medicine, with dentists offering point-of-service medical testing for systemic disease as suggested by the American Dental Association (ADA), would require a paradigm shift, can occur only over a lengthy period, and is unlikely to impact this assessment.

Paediatric applications

Number	Citation	Abstract/ key themes
56	Pedagogical development in local anaesthetic training in paediatric dentistry using virtual reality simulator S. Zafar, et al. European archives of paediatric dentistry: official journal of the	The outcomes of the study suggest that the use of VR can provide an additional mean of LA training in paediatric dentistry; however, it cannot substitute the contemporary model of practice. VR can be used as an adjunct educational tool in the learning of LA as it improves student engagement. With the advancing dental pedagogy, new technologies like VR simulation can be used as an additional tool to support students learning.

	European Academy of Paediatric Dentistry; Feb 2021 *Athens log in required**	
57	Virtual Reality as a novel educational tool in pre-clinical paediatric dentistry training: Students' perceptions S. Zafar, et al. International journal of paediatric dentistry; Nov 2020; vol. 30 (no. 6); p. 791-797 *Abstract only**	Dental students are required to demonstrate competency by pre‐clinical simulated practice before performing invasive clinical procedures on patients. The Moog Simodont® Dental Trainer provides a virtual reality‐based dental simulation environment for training students. One hundred students completed the survey. Fifty‐one per cent of students agreed that using Simodont® assisted their learning, and 56% felt Simodont® training facilitated their understanding of paediatric dentistry tasks. Generally, participants felt more comfortable with simulation training than Simodont® for both practical exercises. Eighty‐eight per cent of the participants disagreed that Simodont® should replace conventional simulation.
58	Effect of augmented reality simulation on administration of local anaesthesia in paediatric patients Rasa Mladenovic, et al. European journal of dental education: official journal of the Association for Dental Education in Europe; Aug 2020; vol. 24 (no. 3); p. 507-512 *Abstract only**	The aim of the study was to evaluate the impact of AR simulator on the perception of learning and acute stress level in students administering local anaesthesia to paediatric patients relative to standard teaching methods. The AR concept may influence better manipulation and control of the syringe in students administering their first anaesthetic injection to paediatric patients, but may not reduce acute stress.
59	Three-dimensional printing in medicine: a systematic review of pediatric applications C. A. Francoisse, et al. Cleft Palate-Craniofacial Journal; Apr 2019; vol. 56 (no. 1); p. 110 *Abstract only**	• This article classifies the pediatric applications of patient-specific three-dimensional printing. • This is a first comprehensive review of patient-specific three-dimensional printing in both pediatric medical and surgical disciplines, incorporating previously described classification schema to create one unifying paradigm. • Understanding these applications is important since three-dimensional printing addresses challenges that are uniquely pediatric including compact

		anatomy, unique congenital variants, greater procedural risk, and growth over time. • We identified four classifications of patient-specific use: teaching, developing, procedural, and material uses. • By classifying these applications, this review promotes understanding and incorporation of this expanding technology to improve the pediatric care.
60	Could Video Glasses Contribute to Behaviour Management in the 21st Century? A, Casaus, et al. Dental update; Jan 2017; vol. 44 (no. 1); p. 45 *Abstract only**	Dental fear in the paediatric population can be a significant barrier to providing optimal dental care. Pharmacological management techniques utilized to manage anxiety, such as conscious sedation and general anaesthesia, are expensive and require specialized equipment with additional staff training. With recent advances in technology, video glasses are an economic and novel distraction technique that may aid in improving behaviour management and facilitate dental treatment. Clinical relevance: Nervous children may find difficulty in accessing care owing to their inability to co-operate and accept dental treatment. This paper describes an innovative technique that may aid the clinician in overcoming this barrier.

Teaching non-clinical skills

Number	Citation	Abstract/key themes
61	Feasibility and usability study of a pilot immersive virtual reality‐based empathy training for dental providers H. Amini, et al. Journal of dental education; Feb 2021 *Abstract only**	Purpose Social determinants of health (SDOH) significantly impact individuals' engagement with the healthcare system. To address SDOH‐related oral health disparities, providers must be equipped with knowledge, skills, and attitudes (KSAs) to understand how SDOH affect patients and how to mitigate these effects. Traditional dental school curricula provide limited training on recognizing SDOH or developing empathy for those with SDOH‐related access barriers. This study describes the design and evaluation of such a virtual reality (VR)‐based simulation in dental training. We hypothesize the simulation will increase post‐training KSAs. Conclusions This pilot study supports using VR SDOH training in dental education. VR technology provides new opportunities for innovative content design.

62	Assessing clinical simulation as a learning tool when training motivation skills in Periodontology—Students' perceptions A. Codeço, et al. European Journal of Dental Education; 2020 *Abstract only**	The prevention and long‐term success of the treatment of periodontal diseases depend on patient compliance with oral health; thus, there is a need to alert and motivate them to control the disease. Clinical simulation emerges as a useful teaching strategy in the development of these clinical skills since it allows the replication of real situations interactively using a simulator or role‐play. Students believe that clinical simulation contributes to an active participation of learners in their learning process, promoting the development of skills such as communication, priority management and decision‐making. They also mention that debriefing is an essential moment of this process, in which the consolidation of knowledge and the structuring of thought are promoted. Students make a positive evaluation of clinical simulation, perceiving it as an effective learning methodology.

Interprofessional education

Number	Citation	Abstract/ key themes
63	Attaining interprofessional competencies by connecting oral health to overall health J. Haber, et al. Journal of dental education; Nov 2020 *Abstract only**	The purpose of this study was to evaluate the effectiveness of an annual oral‐systemic health interprofessional education (IPE) clinical simulation and case study experience with nurse practitioner/midwifery (NP/MW), dental (DDS), medical (MD), and pharmacy (PharmD) students. Student ICCAS results demonstrated statistically significant improvement in self‐reported interprofessional competencies among all types of students across all 3 years ($P < 0.001$); qualitative student comments reflected positive experiences with the Teaching Oral-Systemic Health (TOSH) program. Survey data from IPE faculty facilitators supported the value of the IPE experience for all students. The findings demonstrate the effectiveness of the TOSH program in using oral‐systemic health as a clinical exemplar to develop interprofessional competencies. The 2017‐2019 data reinforce the credibility of scaling the TOSH

		model for developing interprofessional competencies with students from different health professions.
64	The Impact of Oral-Systemic Health on Advancing Interprofessional Education Outcomes J. Haber, et al. Journal of dental education; Feb 2017; vol. 81 (no. 2); p. 140-148 *Abstract only**	The aim of this study was to evaluate the effectiveness of an interprofessional education (IPE) clinical simulation and case study experience, using oral-systemic health as the clinical population health example, for nurse practitioner/midwifery, dental, and medical students' self-reported attainment of interprofessional competencies. The results showed that self-reported interprofessional competencies measured by the ICCAS improved significantly from pre- to posttest for all three student types in 2013 ($p<0.001$) and 2014 ($p<0.001$). Faculty facilitators reported that the IPE clinical simulation experiences were valuable and positively influenced interprofessional communication, collaboration, patient communication, and student understanding of patient care roles. These results suggest that the Teaching Oral-Systemic Health Program Interprofessional Oral-Systemic Health Clinical Simulation and Case Study Experience was effective as a standardized, replicable curriculum unit using oral-systemic health as a population health exemplar to teach and assess interprofessional competencies with nurse practitioner/midwifery, dental, and medical students.

Appendix

Sources and Databases Searched

Healthcare Databases Advanced Search (HDAS) was used to search the following databases: AMED; Medline; CINAHL; BNI; EMBASE; EMCARE; PubMed; HMIC and PsycINFO. Google Scholar was used to citation match and find further relevant papers.

Search Strategies

1. “virtual reality” OR VR
2. “extended reality” OR XR
3. “mixed reality” OR MR
4. “augmented reality” OR AR
5. “clinical simulation” OR “medical simulation” OR “health simulation”
6. tech* AND (immersive OR innovative OR emerging)
7. (dentist* OR dental) AND (education OR training)
8. 1 OR 2 OR 3 OR 4 OR 5 OR 6
9. 7 AND 8

Disclaimer

Searching the literature retrieved the information provided. We recommend checking the relevance and critically appraising the information contained within when applying to your own decisions, as we cannot accept responsibility for actions taken based on it. Every effort has been made to ensure that the information supplied is accurate, current and complete, however for various reasons it may not represent the entire body of information available.

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HEE Knowledge Management team contact details

You can contact the HEE Knowledge Management team on KnowledgeManagement@hee.nhs.uk