REVIEW ARTICLE

The Applications of Augmented Reality (AR) and Virtual Reality (VR) in Teaching Medical and Dentistry Students: A Review on Advantages and Disadvantages

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ABSTRACT

An interactive three-dimensional (3D) experience known as augmented reality (AR) employs computers to superimpose virtual data over the real world. Virtual reality (VR) is the artificial computer reconstruction of a real-life environment or experience. In the last decade, academic medical and dental institutions have witnessed the emergence of teaching technologies created using extended reality technology, such as AR and VR. It has been suggested that these technological advancements might support and further improve the medical and dentistry student teaching process. However, some medical and dentistry educationists are still sceptical about the usage of these technologies. This is because, throughout the centuries, the students in both fields were trained via established conventional methods. The purpose of this paper is to understand the benefit and impediments use of both technologies. We aim to review the advantages and disadvantages of AR and VR applications in the teaching process of medical and dentistry students.
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Keywords: Augmented reality; Virtual reality; Medical and dentistry student; Advantages; Disadvantages

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INTRODUCTION

An interactive three-dimensional (3D) experience known as augmented reality (AR) employs computers to superimpose virtual data over the real world [1]. The AR displays a semi-true image, a virtual object that combines a natural and virtual world that expands or enhances reality with computer-generated elements via the natural environment by a mobile phone, tablet, or AR glasses. Virtual reality (VR) is the artificial computer reconstruction of a real-life environment or experience. It immerses the user by giving them the sensation of being engaged in a simulated reality, primarily by real-time simulation of visuals and audience. Immersion and engagement are the two most important aspects of VR. Immersion denotes the operator's presence in the virtual environment, while interaction denotes the operator's ability to modify [2, 3]. The user experiences a virtual environment through sensory input (sound, sight, and motion) that mimics aspects of the real world. These features include stereo headphones, high-resolution head-mounted displays (HMD), and continuously updated motion-tracking systems [4]. With VR, humans may interact with 3D computer databases effectively in real-time while utilising their innate senses and abilities. The key strength of VR, whether in design or training, is that it supports and improves real-time user interaction [2].

Undergraduate medical and dentistry programmes are conducted within 5-6 years duration. During the first two years of these programmes, which are the preclinical years, the schedules are packed with the syllabus of basic science knowledge to prepare the students for the latter clinical years, whereby foundation knowledge is laid out to the students [5]. For the medical programme, the students are obliged to learn three major basic medical science subjects (i.e., General Anatomy, General Physiology, and General Pharmacology). They learn about the human system body, which comprises several systems which include the respiratory, cardiovascular, alimentary, musculoskeletal, central nervous system, endocrine and reproductive. Dental students are exposed to basic medical science subjects similar to medical students, which are essential as they are going to care for a human patient. Simultaneously, they learn basic dental science subjects, which are the foundation prior to clinical dentistry years.

In First-Year Dentistry, dental students learn three basic medical science subjects (General Anatomy, General Physiology and General Biochemistry) and one basic dental science subject (Oral Biology, also known as Dental Anatomy). Whilst in Second-Year Dentistry, dental students are obliged to learn another three basic medical science subjects (General Pathology, General Microbiology and General Pharmacology) and another basic dental science subject (Applied Dental Science which collaborates the theory part of Dental Materials and the practical part of Dental Simulation). Preclinical medical and dentistry's traditional learning environment is quite challenging years as students need to adapt to a new higher education atmosphere in a new medical language and heavy credit hours. Theory-based learning of the basic medical and dental subjects commonly leaves students with overwhelming feelings of stress and fatigue [6].

Recently, academic medical and dental institutions have witnessed the emergence of a variety of learning and teaching technologies. An evolving, immersive and interactive learning environment can be created using extended reality technology, such as AR and VR. Although AR and VR are similar in the goal of immersing the user, both systems achieve this in different ways. It is suggested that these technological advancements might support and improve the educational process which includes the medical and dental fields. Being among the oldest professions on earth, some traditional educationists still hold on to the conventional way and are still sceptical about the usage of these technologies in teaching medical and dentistry students. This is mostly because, throughout the centuries, both fields were established via conventional methods which include preclinical; practical teaching of wet specimens such as cadavers and in clinical; clinical teaching of using a real person as a simulated patient. Given the rapid development of this technology and the ongoing demand for innovation in the field of higher education for medicine, the purpose of this paper is to understand the benefit and impediments use of extended reality technology.

This paper aims to review the advantages and disadvantages of AR and VR applications in the teaching process of the preclinical and clinical years of medical and dentistry students. This paper will approach this topic structured chronologically from the advantages to disadvantages of the AR and VR applications in teaching preclinical medical students, clinical medical students, preclinical dentistry students and clinical dentistry students.

THE ADVANTAGES OF THE AR AND VR APPLICATIONS IN TEACHING MEDICAL AND DENTISTRY STUDENTS

Preclinical Medical Students

AR and VR may serve as a complimentary online teaching method for undergraduate medical students to understand the anatomical and physiological changes in the human body system in a normal or pathological state [7]. There are five main advantages of AR and VR applications among preclinical medical students reported by the studies: generally cost-effective, ethical leniency, less supervisory constraints, more engagement and enhancing students' learning experience and understanding [8-10].

For the first four advantages of AR and VR, these technologies will allow the students to see the human body system as equivalent and more effective than the traditional face-to-face (FTF) learning method that traditionally utilizes cadavers [8]. Despite cadavers constituting the gold standard for teaching anatomy to medical students, there are significant constraints on their use [4]. Using AR and VR, students can use applications that resemble real cadavers which are more cost-effective as they can dissect the simulated cadaver multiple times and "reset" to its original condition as compared to having to purchase multiple cadavers that are only able to be dissected once. Because they are not using cadavers, which used to be human beings, there is ethical leniency. Students can also explore the applications themselves without needing to be supervised frequently as compared to when using cadavers [4]. As the AR and VR applications already have copyright, thus the source and information embedded are already consented to. However, in traditional teaching using cadavers, dissections must be supervised and there is an ethical way of treating the cadavers, as silent mentors. These methods have specific advantages as compared to conventional cadavers because medical lecturers can teach the human body system with less financial constraint, ethical leniency less supervisory constraints and a more entertaining approach.

For the last advantage, these advanced technologies have been applied in preclinical teaching for more engagement and to improve student's learning experience and understanding [9]. AR and VR are developed to fill in the gaps in the medical education delivery system, which helps the medical student to visualise abstract contents more clearly using 3D graphics instead of textual data [9]. It is more convenient for students to use their mobile devices or a cutting-edge method, such as immersive visualisation using an HMD, which endures continuous improvement for enhanced visualisation and application [10]. In addition, AR will increase users' knowledge and information. With VR, users are also allowed to experiment with an artificial environment. VR in the medical education field encourages learning processes to be conducted in an easier, safer and more comfortable environment.

Clinical Medical Students

The review found four main advantages of AR and VR applications among clinical medical students reported by the studies in view of learning engagement: experiential satisfaction, perceived learning effectiveness by enhancing engagement, a reduction in the learning curve and learning accessibility [11-17].

Firstly, studies indicated that students were satisfied with their AR and VR learning experiences. They reported that the immersive nature of this application made learning more enjoyable and interesting [11-13, 18]. Shiels et al. discovered that medical students preferred learning clinical decision-making skills in a VR simulation session over a case-based discussion [11]. Moreover, Loidl et al. showed in their study that students became more interested in the lesson and in pursuing ophthalmology as a career after completing a week-long ophthalmology module with the inclusion of an AR-based training simulator [18].

Secondly, the studies revealed that when students are more engaged in the session, they perceive their learning to be more effective [12, 13, 19-21]. A study conducted in the United States on communication skills during resuscitation demonstrated that students described the sense of urgency that they felt throughout the learning session, which elicited positive emotional responses that made learning memorable. Furthermore, the students believed that the flexibility and real-time nature of the AR-simulation made learning more effective [19]. Another study from the United Kingdom, comparing learning from 360 films of simulated medical consultation versus traditional two-dimensional consultation, found that the level of students' engagement was maximized as students felt that they were physically, emotionally and mentally involved [13]. The students also reported being able to disconnect from their external surroundings and irrelevant thoughts [20]. Additionally, Kuhn et al. reported that students felt their experience in learning surgical procedures by utilising AR and VR applications has high practical relevance [21].

Thirdly, research has shown that students can shorten their learning curve to gain the necessary knowledge and skills [12, 14, 22]. AR provide useful information layered onto the real world. A study conducted in China employing a 3D hologram showed that medical students made significant progress and achieved a similar result as a radiologist in detecting COVID-19 pulmonary lesions [14]. Furthermore, Torda et al., in their study on teaching the ethical aspect of medical management, reported that students were able to apply their knowledge in real clinical settings as the virtual scenarios were able to capture the complexity of dealing with ethical issues [12].

Finally, AR and VR simulations make learning accessible and flexible [15, 16]. A study conducted by Young et al. used a remote VR experience in which the facilitator can manipulate the VR environment with instructions from students to navigate the VR world [15]. This was conducted during the COVID-19 pandemic to provide medical students with the opportunity to examine paediatric patients in respiratory distress. Students in this study regarded remote VR to be more effective than reading or online learning. Moreover, this approach allows students to interact with patients they would not otherwise encounter in a real clinical setting, particularly during the COVID-19 pandemic. Similarly, Bala et al. used a HMD VR set to conduct a teaching ward round to increase clinical exposure for students during the pandemic [16]. In addition, AR and VR provide the flexibility to standardise learning materials, allowing students to receive consistent knowledge and skills [17]. Boden et al. described how physiological and pathological observations can be standardised using a VR simulator in their work on learning direct ophthalmoscopy using a VR simulator [17].

Preclinical Dentistry Students

There are three main advantages of AR and VR applications among preclinical dentistry students reported by the studies: generally cost-effective, less supervisory constraints, more engagement and enhancing students' learning experience and understanding.

Firstly, AR and VR applications are generally cost-effective. Possessing scientific knowledge to support the practice of dentistry is very important and listed as one of the expected competencies to be achieved among Malaysian dental graduates upon completion of a basic dental degree programme [23]. Students should be able to relate the basic structure of the human body at the organ, tissue, cellular and molecular levels and its functions. It also describes how general health, oral health, nutrition, drugs, and diseases can interact with and affect dental care. Observation of a cadaver is the most traditional method of learning anatomy. However, for each dental school to set up their dissection hall and an anatomy museum would be very costly and impractical. The presence of technologically advanced 3D anatomy visualization and virtual dissection tool, like the Anatomage Table and Sectra, are incredibly beneficial for teaching anatomy and physiology [24, 25]. The technology of interactive medical tables that brings realism out of anatomy concepts on digital bodies' living anatomy and physiology plus real clinical cases aids dental students towards achieving the goals of developing critical thinking in clinical training.

Secondly, AR and VR applications provide less supervisory constraints. During the practical sessions of Applied Dental Science in second-year dentistry, dental students need to practice the procedural procedures in the mouth of a phantom head. Interestingly, DentSim™, an AR advanced dental training simulator, has been introduced and widely used in developed countries [26]. Similar to the traditional simulator, the unit is equipped with a mannequin (phantom head), cutting units and a monitor. However, unlike the traditional one, while a student is seated at a manikin and preparing a preparation, the AR technologies are optically tracked and analysed in real-time the student's handpiece's movement and the typodont-tooth. Therefore, the student can immediately receive their tactile feedback via the unit's monitor and self-assess their procedural progress and accuracy [27].

A student does not need to wait for the supervisor or instructor anymore, who usually needs to supervise about five to ten students per session. Thus, the student can utilize the lab session well and become more productive. At the same time, an instructor or supervisor can focus on the students who need the most help. An instructor can also deliver an explanation more effectively as the student's mental imagery is enhanced optimally via the monitor's visualisation of the intraoral prepared tooth/work [26]. Another slightly different advanced dental simulation, Simodont Dental Trainer, does not equip with the manikin head but still highly incorporates 3D visuals and promises the advantage of the sense of touch to the users [28, 29].

Lastly, AR and VR applications stimulate more engagement and enhance student's learning experience and understanding. The area of dentistry focuses particularly on the study of dental hard and soft tissue (enamel, dentin, pulp, periodontium, and oral mucosa), as well as extraoral structures (salivary glands and temporomandibular joint). It also includes the study of embryology (pre- and post-natal growth), physiology, gross anatomy, histology, and development (salivary glands and temporomandibular joint) [30]. The fundamentals of the mentioned fields are covered in this basic dental science course, which also emphasises the clinical elements and connections to other basic medical science courses. The morphological features of each tooth in the dentition and the evolution of occlusion are the focus of a specific subtopic under the umbrella of Oral Biology known as Tooth Morphology. Possessing a strong foundation in Oral Biology and Tooth Morphology is essential for the Dental Clinical Courses integration during clinical years. It enables dental students who are the 'clinician in training' to achieve the best clinical results while treating patients.

Traditionally, extracted permanent and deciduous teeth with sound, intact morphological features are collected to be used for tell-and-show tooth morphology teaching purposes. Although the cost is almost zero, however, it might be difficult to collect all 32 permanent and 20 deciduous natural teeth. Dental schools can also prepare dentition set casts from dental stone, but the colour and sensation are different from the natural human teeth. Buying available dentition set models in the market is a better solution; however, the price per set is not cheap. To date, there are available real-time 3D mobile applications, like BoneBox™-Dental Lite, featuring human dental anatomy anatomical models for medical education purposes. Dental students can simply download the applications from the online Apps Store, which helps increase their understanding. With regards to the preclinical training in preparation for clinical training, in 2008, the development of a patient-centered VR (PC-VR) training module was conducted [31]. This first experience was conducted on ten patients who received a posterior indirect restoration. The preparation before treating the patients include a digital impression using an intraoral scanner followed by a virtual volumetric model.

Furthermore, the presence of online anatomy quizzes, anatomy board games, online neuroanatomy games and online digestive system games as interactive online learning platforms using AR and VR applications help them to reinforce their anatomy knowledge in the respective anatomy and histology study areas [32]. According to the students, using their own mobile devices to take trivia quizzes on the course topics promoted more interesting interaction and created a more safe and positive learning atmosphere [33].

Clinical Dentistry Students

There are three main advantages of AR and VR applications among clinical dentistry students reported by the studies: shorten learning curve to gain the necessary knowledge and skills, increased patient communication and satisfaction; and enhanced students' learning experience and understanding.

Firstly, clinical dentistry students can shorten their learning curve to gain the necessary knowledge and skills [34, 35]. The use of haptic and VR simulators in preclinical training environments has been demonstrated, with promising outcomes and benefits [36]. However, the application in clinical years has somewhat been under-reported. The most common uses of AR and VR in oral and maxillofacial surgery are dental implantology and orthognathic surgery [37]. Clinically, VR uses a computer-generated simulation of a 3D environment in which people can interact using specifically made electrical instruments, such as in dental implant treatment planning [27, 38]. Mladenovic et al. described that AR group students learning anaesthetic dental procedures displayed better anatomical recognition and greater anaesthetic success compared to students in the conventional group [34]. With the aid of the application, students may practise in a safe setting and make errors, not endangering patients [34].

Secondly, other than improved treatment planning, AR and VR applications also increased patient communication and satisfaction [39]. In this work, 3D models of the patient's teeth and other oral and extraoral components were created using laser scanning to create VR applications that were then loaded into a simulator. Then, a dentist can use this simulator to practise and do assessments before performing the procedure on a real patient in a variety of dental specialities, including orthodontics, oral and maxillofacial surgery, restorative dentistry, dental public health, and dental education. This system incorporates automated data recording, enabling users to perform postoperative analysis and self-evaluation [40].

Thirdly, VR had a good impact on students' learning experience and understanding [31]. Research conducted in Serbia by incorporating serious games as a teaching tool to improve dental students' local anaesthesia administration skills revealed that student regarded their experience favourably [34]. The module made it feasible to handle unexpected procedural concerns, effectively prepare for irreversible procedures, and prevent potential harm. Students described their confidence levels were achieved, and the usefulness of the PC-VR has provided them with unlimited training opportunities. This further will increase in safety of dental care. In addition, the capabilities of digital records provide an opportunity for interprofessional discussion and calibration. Utilizing this technology may also help with ethical and safety concerns related to patient care, competency evaluation, and dental training. Moreover, VR simulators facilitate further integration with other digital dental software programs and 3D printing/milling devices [41].

THE DISADVANTAGES OF THE AR AND VR APPLICATIONS IN TEACHING MEDICAL AND DENTISTRY STUDENTS

Preclinical Medical Students

As with any technological advancement, using AR and VR as tools must be employed appropriately to be effective. Despite the immense promise of AR and VR and the advantages discussed above, there are five disadvantages in these technologies' applications among preclinical medical students reported by the studies: issues of ineffectiveness or misuse, ineffective cost and bulky HMDs with a small field of view; security issues when AR data is altered to affect worker decisions; an expensive and steep learning curve a lack of precise spatial placement systems for AR items and impair the human contact [8, 42-44]. Amongst the five disadvantages, the main factors are ineffective cost and bulky HMDs; and impairment of human contact.

AR and VR applications initially contribute to ineffective costs with bulky HMDs. For many years, the main barriers to using VR in education were the cost and computing power required to create realistic environments [42, 43]. Advanced technology is often expensive. Also, certain AR and VR systems were challenging to use, and the gear that users were required to wear was cumbersome and hampered [8]. During that time, HMDs have a nerdy appearance and will only be utilised in a limited number of situations; and the perception was that they are not intended for general use in the near future. Fortunately, developments in mobile device technology have made this possible, as well as reduced the size of VR equipment [44]. By compromising on quality reduction, mobile devices with inexpensive viewers, such as Google Cardboard, have made VR incredibly accessible.

Furthermore, AR and VR applications cause impairment of human contact. While VR can be an asset in most fields of endeavour, it can also be a disadvantage in traditional education which is built on personal human communication and interpersonal interactions. VR is different; it is only between the user and the software. It can impair the relationships between students and human contact. VR can be a solitary, isolated experience that transports you to a different location that is not part of your current surroundings. This is the opposite result of the primary objectives of the conventional method of teaching medicine by bringing individuals together which improves human-to-human interaction and encourages group interaction.

Clinical Medical Students

The review discovered three major drawbacks of AR and VR applications among clinical medical students cited by the studies: technology concerns, financial issues, and compatibility issues [12].

Firstly, there is an additional technological learning curve that students must acquire to utilize AR or VR technology. Application of technology necessitates familiarity with its hardware and software. For example, it requires time to configure the headset, explain the controls, display the material for the user and for the user to adjust to the virtual world [16, 19]. Hess et al. reported that at the beginning of the simulation exercise, students experienced difficulties in trying to manipulate the AR equipment as well as in resizing and relocating the holographic image [19]. There is an additional cognitive burden from learning the technology that students must master in addition to the primary learning purpose [19]. Issues with network speed, image and sound quality may lead to users' frustration and negatively impact their experience [16]. Image identification and tracking is an AR feature that allows applications to recognise 2D pictures and trigger the creation of augmented digital images, such as 3D photographs, videos, and 360-degree panoramas.

Secondly, compatibility issues with this technology may pose a barrier to using this technology. Another medically related condition that might be incompatible with using this technology is those with seizures and who are wearing corrective glasses. Hess et al. had to exclude students with seizures, severe motion sickness and wearing glasses from the study [19]. Whereas, in real life, educators should ensure that all students receive the same learning opportunity to get the optimal outcome and benefit from their learning session. Moreover, compatibility between hardware and software may pose an additional challenge. For example, Omlor et al. found that the software used in their study is only compatible with a limited number of online platforms [13].

Finally, the cost of VR and AR applications poses a challenge in their implementation. The technology needs to utilize both hardware and software, which incurs expenses [13, 19, 20]. For example, the price of a good VR or AR headset is costly. On top of that, the VR and AR market is fragmented, which increases the expenses of purchasing individual equipment. Cost is expected to increase proportionally with a product's degree of technology. A study conducted had to choose between price and functionality in selecting the more suitable camera to create an adequate degree of immersion in the study [13]. Realism in AR and VR can be enhanced through the perception of touch. This can be accomplished with the use of haptic technologies or task trainers [19]. Hess et al. reported that students believed adding a mannequin to a hologram would further enhance their experience [19]. However, as more advanced technologies and new modalities are introduced, costs will also increase.

Preclinical Dentistry Students

The review discovered three major drawbacks of AR and VR applications among preclinical dentistry students cited by the studies: supervisor surveillance, development of customised technology and huge investment cost for the initial set-up.

Although AR and VR technologies offer positive motivation and performance outcomes following their friendly atmosphere, general satisfaction; excitement; engagement; fun, and realistic learning environment, this assumption cannot be generalised without further studies [27, 33, 45]. Students still need to build their baseline anatomy and histology understanding of the VR and AR that they were viewing with the help and supervision of instructors or educators [33]. Moreover, most of the available or offered VR and AR platforms were not specially developed for dentistry education [33]. For example, although the use of Simodont dental simulators does improve performance and preclinical skills, dental students still require hours of practice on plastic and natural teeth to complement their undergraduate training [28]. The cost of Simodont AR dental simulators themselves is not cost-effective.

Clinical Dentistry Students

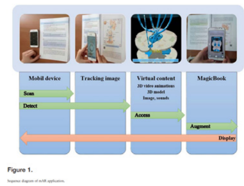
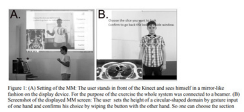
The review discovered four major drawbacks of AR and VR applications among clinical dentistry students cited by the studies: realism, cybersickness, risk of data privacy and security violations and time constraint to master the skill.

Firstly, the realism of VR and dentist's office simulation is one of the disadvantages of this technology [46]. Different hardness for enamel and dentin, soft tissues, saliva, and patient movement make VR experiences less authentic due to these differences. Furthermore, the presence of saliva and movement of the tongue in a real situation limits the experiences in VR, thus considered as a limitation of VR in clinical dentistry.

Secondly, cybersickness, commonly referred to as digital motion sickness, is a cluster of symptoms comparable to those experienced by persons who suffer motion sickness. This can be triggered by AR or VR experience that simulates motion. Rodrigues et al. reported that students experience mild symptoms of cybersickness, such as headache, visual fatigue, difficulty in maintaining focus and blurred vision [36].

Thirdly, the dentist and the auxiliary teams are in charge of managing data, which carries a risk of data privacy and security violations. AR and VR applications may raise challenges such as large data availability and trusted sharing. Many systems using software-like algorithms designed to simulate human cognitive processes in healthcare decision-making are in charge

Table I : The advantages and disadvantages of AR and VR applications in teaching preclinical and clinical medical students

Reference article	VR and AR application type	Target populations	Application usage	Mechanisms	Advantages	Disadvantages
				Preclinical medical students		
(Kucuk et al. 2016)	MagicBook uses mobile AR (mAR) technology.	Preclinical medical students: 70 second-year medical students.	Learning anatomy.	 Figure 1. By using mobile AR (mAR), this technology was established for neuroanatomy topics integrating virtual learning objects into the real world and allowing users to interact with the environment using mobile devices. Using marker-based mAR technology, multimedia materials for teaching anatomy are combined with traditional books.	The use of mAR applications contributes to increased achievement and lesser cognitive load. An effective and productive learning environment is created by using these applications. The materials in the MagicBook are accessible for the students anytime and anywhere.	The operation of mAR applications requires an internet connection, thus limiting the access of some students to the materials. The insufficiency of certain technical features of the students' smartphones may cause them problems in operating the mAR software.
(Moro et al. 2017)	AR and VR.	Preclinical medical students: 59 participants studying anatomy including 84.7% (n=50) of biomedical and health sciences students, 8.5% of medical students (n=5), and 6.8% of students from other faculties (n=4).	Learning anatomy.	Using VR or AR devices for learning skull anatomy, which is as valuable as tablet-based (TB) applications.	Both VR and AR augment the immersion, engagement and enjoyment of the learners.	Adverse effects including headaches, dizziness and blurred vision are more likely to be experienced by VR learners.
(Kugelmann et al. 2018)	Augmented Reality Magic Mirror (AR MM) system.	Preclinical medical students: 880 medical students.	Learning gross anatomy.	 The RGB-D sensor is utilized, allowing the system to link a section image that has been deposited to the projection of the user's body, and a large display resembling a real-world physical mirror.	The system increases the anatomical knowledge and motivation of the learners and thus is perceived as beneficial in comparison to learning section images using traditional textbooks. The system offers a great first contact to section images and interactive components. The 3D understanding of human anatomy is also augmented using this system as it allows the learners to switch and slice through different section images and intersecting planes including horizontal, sagittal and vertical. The system also enhances active learning and knowledge about the human gross anatomy that has been learnt previously can be transferred to clinically relevant subjects.	The software failed frequently or hangs itself up. The male and female section images of the whole body such as CT and MRI scans are lacking. The option to freeze a specific section image could be included in the system to allow the learners to observe a specific section image statically. The graphical user interface and resolution of the section images could be upgraded.

Clinical medical students						
(Torda 2020)	Clinical scenario filmed with VR technology.	Medical students in learning medical ethics.	Incorporation of clinical scenario video, filmed using virtual reality technology in a medical ethics module.	Clinical scenario teaching in a medical ethics module utilising virtual reality technology. Clinical scenarios were captured using a 360-degree camera and could be viewed via 3D technology to create a VR experience for the viewer.	Allow students to be exposed to various scenarios that they might not have the chance to encounter during clinical practice. High level of student engagement, learning gain and clinical application.	Technical issue: slow download speed of videos. The different learning styles of the students (some students prefer to have written scenarios rather than watch the full videos).
(Loidl et al. 2020)	Eyesi Indirect, VRmagic Holding AG, Mannheim, Germany.	Clinical medical students: medical students in ophthalmology posting.	Clinical examination of the eye, including the fundus examination. Learning the usage of ophthalmoscopy.	Integration of AR-based training simulator into ophthalmology teaching.	AR simulator can serve as a replacement for a head or human model. Create a favourable impact on students, particularly concerning their learning motivation and career choice.	Unable to completely replace training on a real person.
(Boden et al. 2020)	VR simulator for learning direct ophthalmoscopy.	Clinical medical students: medical students in ophthalmology posting.	Learning direct ophthalmoscopy on a simulator.	Integration of VR simulator training into ophthalmology teaching.	Able to standardise teaching materials, for example, physiological and pathological findings.	-
(Young et al. 2021)	OculusRift headset.	Clinical medical students: medical students in paediatric posting.	Application of VR in remote video-teleconferencing to teach bedside paediatric patient assessment during COVID -19 pandemic.	Students participate in teleconferencing sessions via the Zoom platform with a pediatric faculty instructor. The instructor donned an oculusRift headset and the image is projected into the platform via the screen share function. The virtual platform is created on and delivered through the Unity game engine. Students navigate through the virtual world via instruction to the facilitator.	Allow accessibility to learning when FTF teaching is not an option. VR may serve as a supplement for bedside teaching. Allow feasibility of remote learning.	Costly equipment that makes it difficult to be replicated in other institutions.
(Liu et al. 2021)	StarCloud (a 3D reconstruction software from Visual3D). Microsoft HoloLens (Microsoft Corp).	Medical students, radiologists and surgeons.	Identification of lung lesions caused by COVID-19.	Application of 3D hologram with mixed reality techniques in learning to identify pulmonary lesions of COVID-19.	Reduce the learning curve. Digital anatomical imaging serves as an alternative to the use of cadavers. Less costly than the use of a cadaver.	A significant collection of disease images for reconstruction. Need software and hardware technological expertise.

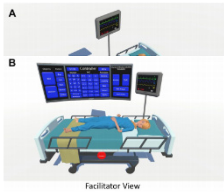
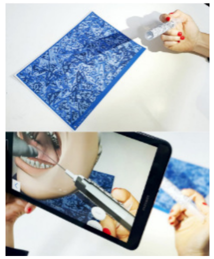
(Bala et al. 2021)	Microsoft Holo-Lens.	Medical students.	Remote teaching ward rounds during the COVID-19 pandemic.	 Application of head-mounted Holo-Lens2™ technology by the clinician during ward rounds to enable students to visualise the clinical environment in real-time. Students were able to listen to the patient and interact with the clinician.	Allow feasibility of clinical teaching, particularly when access to the ward is restricted during the COVID-19 pandemic. Allow access to uncommon patients that students seldom encounter. Enable the same clinical experience to benefit multiple students that would otherwise not be possible with the usual clinical experience.	Holographic images may present their unique problems such as poor image quality or inadequate lighting.
(Hess et al. 2022)	Mobile AR Education, Magic Leap One (ML1) headset, Chariot Augmented Reality Simulator Chariot Reality Medical Simulator (CHARM).	Medical students and physician assistant students.	Incorporation of an AR Simulator into an Advance Cardiovascular Life Support Simulation Scenario to teach communication skills during a medical crisis.	 Integrating real-time communication into a portable medical simulator with a holographic patient and monitor utilising Augmented Reality Medical simulator (CHARM), Mobile AR Education (MARE) framework and Magic Leap One Headset.	Encourage remote and collaborative learning. Increase learning satisfaction and student engagement. Allow flexibility to modulate scenario difficulty according to trainee response.	Increase cognitive load in which students need to learn how to use the technology in addition to the actual learning objective.
(Omlor et al. 2022)	180° 3D Lenovo mirage camera.	Medical students.	Video-assisted teaching in internal medicine procedures.	 Utilising virtual reality equipment to capture various internal medicine procedures and enable students to watch the videos as immersive 3D VR using a goggle cardboard headset.	Increase learning satisfaction and improve understanding of the topic.	Cost: To capture better feature, a more expensive camera, (360° 3D) need to be used. The study had to use a 3D 180deg Lenovo camera that compromises between features and price. Compatibility issue: the video is not compatible with some learning platforms.
(Jacobs and Maidwell-Smith 2022)	Samsung gear VR headset.	Medical students.	Learning medical consultation of an abdominal pain medical encounter.	 Watch the video as an immersive 3D experience using Samsung Gear Headset.	Improve students' engagement with the learning environment. Allow flexibility in learning. Engagement in the learning activity.	Support individual learning rather than group learning. Cost: might not be affordable to all institutions. The technology is still not a replacement for a real-life patient encounter.

Table II : The advantages and disadvantages of AR and VR applications in teaching preclinical and clinical dentistry students

Reference Article	VR and AR application type	Target population	Application usage	Mechanisms	Advantages	Disadvantages
Preclinical dentistry students						
(Dyulicheva et al., 2021)	VR simulator for dental students training developed for Oculus Quest. 2 VR headsets with six degrees of freedom.	Preclinical dental students.	A VR simulator dental clinic and simulation of tooth drilling.	Caries free exercise and practice in VR.	Capable of simulating the Visual experience in the simulation process.	Unable to stimulate tactile sensation and feedback from the drilling.
(Zainal et al., 2022)	Review on AR & VR on preclinical training of medical and dental students.	Preclinical medical and dental students.	Review on the use of AR & VR during the pandemic of COVID-19.	Teaching and learning for preclinical students of medical and dental.	Offers a range of interesting and exciting and alternative ways of teaching and learning.	The steep learning curve for both students and teachers. Potential discouraging to the students and teachers.
Clinical dentistry students						
(Huang et al., 2018)	Multiple applications between AR and VR.	Clinical dental students.	As part of OSCE or training of dental students and surgical residents.	The combined uses of surgical instruments, tracking systems, medical images and computers for real-time training.	Provide 3D information and improve accuracy of the procedures such as minor oral surgery and implants.	Currently, AR and VR training needs additional tools to increase the success rate of training. It could not be used alone.
(Ayoub & Pulijala, 2019)	Applications for VR and AR technologies that enable dental surgery and implant placements.	Clinical dental students.	Assess the usage of VR in different dental specialities.	Review of systematic review, expert review, case reports, etc.	VR gives additional benefits in dental implant planning and orthognathic surgical planning.	Limited prospective data comparing VR and standard delivery.
(Haleem & Javaid, 2020)	Review on customization of treatment options using digital information.	Clinical dental students.	Digital information translation, and smart manufacturing technologies usage in dentistry.	A narrative review on AR & VR on customization of treatments especially implants.	Simplification of treatment and efficient way to overcome issues related to complex procedures and cases.	Higher capital investment to adapt to the new technologies.
(Haleem et al., 2020)	Review on unconventional ways to identify dental disease.	Clinical dental students.	Examples of AR and VR usage in dental training.	A narrative review on AR & VR applications for clinical training.	Extensive application for planning, training, therapeutic treatments and pain management in dentistry.	Cost of the application and lack of knowledge and awareness about the existence of AR & VR.
(Serrano et al., 2020)	An intraoral optical impression system converted by software (Nissin Dental Products Inc.).	Clinical dental students.	The real-life practice of doing fillings on patients.	3D scanning of real patients with tooth problems and practice virtually before doing it in the patient's mouth.	A better view of the tooth with issues, unlimited possibilities of treatment on the same tooth over virtual data and room for mistakes and improvements.	Differences between the hardness felt between tooth structures, soft tissues and patient movements.
(Alauddin et al., 2021)	Review the interplay between ICT, AR & VR, and AI.	Clinical dental students.	Multiple reviews involving advancement in digital technologies related to dentistry.	Digital scanning for implants and surgery, tele-dentistry for remote access dental consultations.	Limits the FTF contact between dentists and patients, Shorten the duration of treatment and be cost-effective in the future.	Limitation on data acquisition from person to person and the safety of information and data in the cloud from tampering or hacking.

(Hattori et al., 2022)	Simodont (Nissin Dental Products Europe BV, Nieuw-Vennep, Netherlands).	Clinical dental students.	Virtual simulation on the crown formation.	Virtual simulation vs mannequin simulation.	Cost-effective, data was constructed using the image to compare with the standard.	The final assessment of the margin design and volume cut of the crown is not as expected.
(Mladenovic et al. 2022)	Mobile simulator application (Dental Simulator v1.13 for iOS and Android) using study mode, simulation mode and AR mode.	Clinical dental students.	Training dental students' local anaesthesia administration technique.		Shorten the cognitive and psychomotor learning curve. Ease of access-students has the flexibility to learn at their own pace. Freedom to make mistakes and learn from their actions and consequence. Easy to use.	Additional technology and effects are required to enhance the immersion and realism, which will incur additional costs.
Preclinical and clinical dentistry students						
(Nincarean et al., 2013)	Multiple mobile-based AR applications.	General educational population.	As part of new methods to enhance the learning experience.	The use of multiple types of applications for different types of subjects.	Improve the learning experience for both the teachers and the students.	More research is needed into the pedagogical and learning theory using the AR application.
(Fahim et al., 2022)	Review of the ongoing process of incorporation of AR & VR into dental, medicine and education and the practical usage.	Preclinical and clinical dental students.	Multiple usage assessments from oral hygiene education to advance surgical procedures.	Reviews of 20 research papers on AR & VR performed for various dental specialities.	Beneficial tools to enhance the learning experience and possible usage for dental phobia patients.	No scientific recommendation due to low numbers of research.
(Rodrigues et al. 2022)	DENTIFY, a multimodal immersive simulator, combines a Head-mounted VR display (Oculus Quest), a haptic pen (3D System Touch Haptic Device) designed as a dental turbine and 3D sound of dental drilling to assist Operative Dentistry learning.	Preclinical and clinical dental students.	Operative dentistry learning. Virtual simulation on caries removal and fillings.	  DENTIFY can immerse a user in a virtual environment composed of visual, auditory and haptic stimuli. It combines a haptic pen, VR headsets, dental turbines drilling sounds, patient-specific teeth models and a laptop. DENTIFY consists of 13 sessions of caries-free training and assessment.	Improve learning effectiveness as it promotes self-evaluation and multimodal immersion of the simulated dental drilling experience. Caries can be virtually created. Easy access to different types of cavities to practice.	Steep learning curve. Participants need to get used to practising without the real handpiece. Cost: The technology needs to utilize both hardware and software.

of protecting the privacy of patient data. Although the application is carried out either under supervision or without it in the context of law and jurisprudence, the systems are not held responsible for this [41].

Lastly, time constraints to master skills. Skills acquired to master this technology are attributed to educators in dental school settings. To adjust and become fully immersed in the virtual environment, both educators and students needed some time [46]. Image identification and tracking is an AR feature that allows applications to recognise 2D pictures and trigger the creation of augmented digital images, such as 3D photographs, videos, and 360-degree panoramas. Having a detection system and sensors with low sensitivity may pose a challenge as it disrupts the natural flow of the image-tracking process and, eventually, the user's learning experience [34].

CONCLUSION

In summary, the integration of AR and VR in the medical and education field offers various positive advantages such as experiential satisfaction, perceived learning effectiveness by students, increment of students' engagement and understanding in the simulated experiences, a reduction in the learning curve and improvement of learning accessibility. The usage of these technologies in preclinical and clinical training gives opportunities for medical and dentistry students to train their skills by themselves and even repeat the procedure multiple times until they feel that they are competent enough. However, both technologies also present some challenges, including technological hurdles, budgetary restrictions and compatibility issues. The user needs to consider all factors, including educational requirements, available resources and health concerns, in order to gain maximum benefit from using this technology. Furthermore, to have a complete VR and AR system in the hardware with abundant included accessories could be very costly to the medical school. We believe both AR and VR will be successful in supplementing the teaching of the medical and dentistry students as both technologies are becoming more accessible and affordable. Future applications of both technologies can be expected to be quite creative, and they may even fundamentally change the way we interact and work. However, it is imperative to emphasise that traditional teaching methods are still essential for medical and dental education and that both AR and VR are only primarily supplemental learning aids.

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REFERENCES

1. Kucuk S, Kapakin S, Goktas Y. Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load. Anat Sci Educ. 2016;9(5):411-21. doi: 10.1002/ase.1603.
2. McCloy R, Stone R. Virtual reality in surgery. BMJ. 2001;323(7318):912-5. doi: 10.1136/bmj.323.7318.912.
3. Joda T, Gallucci GO, Wismeijer D, Zitzmann NU. Augmented and virtual reality in dental medicine: A systematic review. Comput Biol Med. 2019;108:93-100. doi: 10.1016/j.compbiomed.2019.03.012.
4. Moro C, Stromberga Z, Raikos A, Stirling A. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. Anat Sci Educ. 2017;10(6):549-59. doi: 10.1002/ase.1696.
5. Hogh A, Muller-Hilke B. Learning strategies and their correlation with academic success in biology and physiology examinations during the preclinical years of medical school. PLoS One. 2021;16(1):e0245851. doi: 10.1371/journal.pone.0245851.
6. Malau-Aduli BS, Lee A, Alele F, Adu M, Drovandi A, Jones K. Preclinical to clinical transition experiences of dental students at an Australian Regional University. Eur J Dent Educ. 2022;26(1):182-96. doi: 10.1111/eje.12687.
7. Kugelmann D, Stratmann L, Nuhlen N, Bork F, Hoffmann S, Samarbarksh G, et al. An Augmented Reality magic mirror as additive teaching device for gross anatomy. Ann Anat. 2018;215:71-7. doi: 10.1016/j.aanat.2017.09.011.
8. Ray AB, Deb S. Smartphone Based Virtual Reality Systems in Classroom Teaching — A Study on the Effects of Learning Outcome. 2016 IEEE Eighth International Conference on Technology for Education (T4E)2016. p. 68-71.
9. Duarte ML, Santos LR, Guimaraes Junior JB, Peccin MS. Learning anatomy by virtual reality and augmented reality. A scope review. Morphologie. 2020;104(347):254-66. doi: 10.1016/j.morpho.2020.08.004.
10. Zhan T, Yin K, Xiong J, He Z, Wu ST. Augmented Reality and Virtual Reality Displays: Perspectives and Challenges. iScience. 2020;23(8):101397. doi: 10.1016/j.isci.2020.101397.
11. S-A S, Fadipe A, Hundle A, Williams J, Warren R, Higham H. REAL LEARNING IN A VIRTUAL EMERGENCY: COMPARING TEACHING METHODS FOR MEDICAL STUDENTS. BMJ simulation and technology enhanced learning. 2019;5:A12. doi: 10.1136/bmjstel-2019-aspihconf.21.
12. Torda A. CLASSIE teaching - using virtual reality

to incorporate medical ethics into clinical decision making. BMC medical education. 2020;20:326. doi: 10.1186/s12909-020-02217-y.
13. Omlor AJ, Schwдrzel LS, Bewarder M, Casper M, Damm E, Danziger G, et al. Comparison of immersive and non-immersive virtual reality videos as substitute for in-hospital teaching during coronavirus lockdown: a survey with graduate medical students in Germany. Medical education online. 2022;27:2101417. doi: 10.1080/10872981.2022.2101417.
14. Liu S, Xie M, Zhang Z, Wu X, Gao F, Lu L, et al. A 3D Hologram With Mixed Reality Techniques to Improve Understanding of Pulmonary Lesions Caused by COVID-19: Randomized Controlled Trial. J Med Internet Res. 2021;23(9):e24081. doi: 10.2196/24081.
15. Young D, Real FJ, Sahay RD, Zackoff M. Remote Virtual Reality Teaching: Closing an Educational Gap During a Global Pandemic. Hospital pediatrics. 2021;11:e258-e62. doi: 10.1542/hpeds.2021-005927.
16. Bala L, Kinross J, Martin G, Koizia LJ, Kooner AS, Shimshon GJ, et al. A remote access mixed reality teaching ward round. The clinical teacher. 2021;18(4):386-90. doi: 10.1111/tct.13338.
17. Boden KT, Rickmann A, Fries FN, Xanthopoulou K, Alnaggar D, Januschowski K, et al. [Evaluation of a virtual reality simulator for learning direct ophthalmoscopy in student teaching]. Der Ophthalmologe : Zeitschrift der Deutschen Ophthalmologischen Gesellschaft. 2020;117:44-9. doi: 10.1007/s00347-019-0909-z.
18. Loidl M, Schneider A, Keis O, Цchsner W, Grab-Kroll C, Lang GK, et al. [Augmented Reality in Ophthalmology: Technical Innovation Complements Education for Medical Students]. Klinische Monatsblatter fur Augenheilkunde. 2020;237(5):689-98. doi: 10.1055/a-0767-7063.
19. Hess O, Qian J, Bruce J, Wang E, Rodriguez S, Haber N, et al. Communication Skills Training Using Remote Augmented Reality Medical Simulation: a Feasibility and Acceptability Qualitative Study. Medical science educator. 2022;32(5):1005-14. doi: 10.1007/s40670-022-01598-7.
20. Jacobs C, Maidwell-Smith A. Learning from 360-degree film in healthcare simulation: a mixed methods pilot. Journal of visual communication in medicine. 2022;45(4):223-33. doi: 10.1080/17453054.2022.2097059.
21. Kuhn S, Huettl F, Deutsch K, Kirchgдssner E, Huber T, Kneist W. [Surgical Education in the Digital Age - Virtual Reality, Augmented Reality and Robotics in the Medical School]. Zentralblatt fur Chirurgie. 2021;146(1):37-43. doi: 10.1055/a-1265-7259.
22. Xie H, Gao F, Zheng X. Research and application of a teaching platform for combined spinal-epidural anesthesia based on virtual reality and haptic feedback technology. Anesthesia and analgesia. 2021;133(3 SUPPL 2):579-80.
23. Council MD: Competencies Of New Dental Graduates, Malaysia- V2-2021. https://mdc.moh.gov.my/uploads/competencies_of_new_dental_grad_20222.pdf (2022). Accessed 30th March 2023.
24. Anatomage I: Anatomage Table. https://anatomage.com/ (2018). Accessed 20.
25. Bhd IS: Sectra The Interactive Medical Table. https://indizium.com/product/sectra/ (2014). Accessed 30th March 2023.
26. Bhd IS: DentSim. https://indizium.com/product/dentsim (2014). Accessed 2023 30th March.
27. Huang TK, Yang CH, Hsieh YH, Wang JC, Hung CC. Augmented reality (AR) and virtual reality (VR) applied in dentistry. The Kaohsiung journal of medical sciences. 2018;34(4):243-8. doi: 10.1016/j.kjms.2018.01.009.
28. Products ND: Simodont Dental Trainer. https://www.simodontdentaltrainer.com (2018). Accessed 30th March 2023.
29. Hattori A, Tonami KI, Tsuruta J, Hideshima M, Kimura Y, Nitta H, et al. Effect of the haptic 3D virtual reality dental training simulator on assessment of tooth preparation. Journal of dental sciences. 2022;17(1):514-20. doi: 10.1016/j.jds.2021.06.022.
30. Medicine SBSoD: Curriculum Guidelines for the Development of Graduate Programs in Oral Biology. https://dentistry.stonybrookmedicine.edu/aaob/graduate_guidelines (1986). Accessed 30th March 2023.
31. Serrano CM, Wesselink PR, Vervoorn JM. First experiences with patient-centered training in virtual reality. J Dent Educ. 2020;84(5):607-14. doi: 10.1002/jdd.12037.
32. Perumal V, Dash S, Mishra S, Techataweewan N. Clinical anatomy through gamification: a learning journey. The New Zealand medical journal. 2022;135(1548):19-30.
33. Felszeghy S, Pasonen-Seppдnen S, Koskela A, Nieminen P, Hдrkцnen K, Paldanius KMA, et al. Using online game-based platforms to improve student performance and engagement in histology teaching. BMC Med Educ. 2019;19(1):273. doi: 10.1186/s12909-019-1701-0.
34. Mladenovic R, AlQahtani S, Mladenovic K, Bukumiric Z, Zafar S. Effectiveness of technology-enhanced teaching methods of undergraduate dental skills for local anaesthesia administration during COVID-19 era: students' perception. BMC Oral Health. 2022;22(1):40. doi: 10.1186/s12903-022-02077-6.
35. Mladenovic R, Matvijenko V, Subaric L, Mladenovic K. Augmented reality as e-learning tool for intraoral examination and dental charting during COVID-19 era. J Dent Educ. 2021. doi: 10.1002/jdd.12780.
36. Rodrigues P, Esteves A, Botelho J, Machado V, Zagalo C, Zorzal ER, et al. Usability,

acceptance, and educational usefulness study of a new haptic operative dentistry virtual reality simulator. Computer methods and programs in biomedicine. 2022;221:106831. doi: 10.1016/j.cmpb.2022.106831.
37. Ayoub A, Pulijala Y. The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery. BMC Oral Health. 2019;19(1):238. doi: 10.1186/s12903-019-0937-8.
38. Haleem A, Javaid M, Khan IH. Virtual reality (VR) applications in dentistry: An innovative technology to embrace. Indian journal of dental research : official publication of Indian Society for Dental Research. 2020;31(4):666-7. doi: 10.4103/ijdr.IJDR_501_19.
39. Haleem A, Javaid M. Industry 4.0 and its applications in dentistry. Indian journal of dental research : official publication of Indian Society for Dental Research. 2020;31(5):824-5. doi: 10.4103/ijdr.IJDR_904_18.
40. Fahim S, Maqsood A, Das G, Ahmed N, Saquib S, Lal A, et al. Augmented Reality and Virtual Reality in Dentistry: Highlights from the Current Research. Applied Sciences. 2022;12(8):3719.
41. Alauddin MS, Baharuddin AS, Mohd Ghazali MI. The Modern and Digital Transformation of Oral Health Care: A Mini Review. Healthcare (Basel, Switzerland). 2021;9(2). doi: 10.3390/healthcare9020118.
42. Merchant Z, Goetz ET, Cifuentes L, Keeney-Kennicutt W, Davis TJ. Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. Computers & Education. 2014;70:29-40. doi: 10.1016/j.compedu.2013.07.033.
43. Bell JT, and H. Scott Fogler. Virtual reality in chemical engineering education. Proceedings of the 1995 Illinois/Indiana ASEE Sectional Conference. 1995.
44. Wu H-K, Lee SW-Y, Chang H-Y, Liang J-C. Current status, opportunities and challenges of augmented reality in education. Computers & Education. 2013;62:41-9. doi: 10.1016/j.compedu.2012.10.024.
45. Nincarean D, Alia MB, Halim NDA, Rahman MHA. Mobile Augmented Reality: The Potential for Education. Procedia - Social and Behavioral Sciences. 2013;103:657-64. doi: https://doi.org/10.1016/j.sbspro.2013.10.385.
46. Dyulicheva YY, Gaponov DA, Mladenović R, Kosova YA. The virtual reality simulator development for dental students training: a pilot study. International Workshop on Augmented Reality in Education2021.