OPEN ACCESS
Journal of Advances in Education and Philosophy
Abbreviated Key Title: J Adv Educ Philos
ISSN 2523-2665 (Print) |ISSN 2523-2223 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Review Article

From Real to Virtual-Technology Assisted Instruction in Preclinical Dental Education

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DOI: 10.36348/jaep.2021.v05i07.003 | **Received:** 07.06.2021 | **Accepted:** 10.07.2021 | **Published:** 16.07.2021

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Abstract

Training dental students is a complex process as it requires the acquisition of fine motor skills, and hand-foot and eye coordination to perform clinical work, in addition to the attainment of knowledge. Awareness of limitations of conventional simulators that have been used for pre-clinical training for this purpose, has paved way for digital dentistry as the new pedagogical paradigm that offers multiple advantages over conventional dental teaching methods (Zafar *et al*., 2020). Digital innovations including virtual reality (VR) and augmented reality (AR) are becoming more prevalent in dentistry (Dutã *et al*., 2011 in Zafar *et al*., 2020). This paper reviews some of the recent methods such as computer assisted simulators, virtual patients, virtual teeth, use of MultiUser Virtual environment, etc., and highlights the benefits of using these for the preclinical training in dental education. The need for the new age facilitators to adopt to and employ the newer technology based methods of instruction has also been emphasized.

Keywords: Virtual reality, Augmented reality, Computer assisted simulations, Virtual patient, MultiUser Virtual environment, Preclinical dentistry.

INTRODUCTION

The goal of dental education is to develop future competent oral health care professionals, who serve their patients and communities well, and strive to better their knowledge and skills lifelong. Hence the emphasis during training is not just on the cognitive domain, but on the affective and more importantly, clinical (psychomotor) domains of learning as well. It is incumbent upon dental schools to equip their graduates with the skills and knowledge to enable them to practise competently, compassionately and independently, without supervision, as described by McGleenon & Morison, in 2021.

Since in dentistry, both intellectual and manual dexterity skills of an operator are the key elements, most dental curricula include didactic, preclinical and clinical training (Hanson, 2011 in Zafar *et al*., 2021). Training dental students is a complex process as it requires the acquisition of fine motor skills, and hand-foot and eye coordination to perform clinical work, in addition to the attainment of knowledge. Before performing invasive clinical procedures on patients, it is important that dental students reach adequate competency and this is achieved through extended use of pre-clinical simulated practice (Chan *et al*., 2000; Suvinen *et al*., 1998 in Zafar *et al*., 2020).

As a practical vocation, dentistry has always drawn on simulation as an essential part of student clinician education. In the early days of dental training, real teeth were used in a bench-top setting before the introduction of the phantom head (Perry *et al*., 2015).

Dental students obtain their surgical skills training from various sources. Traditional methods relied on practicing procedural skills on plastic teeth or live patients under the supervision of dental experts. This master-apprentice type of training is now being challenged by complications such as increasing cost of training materials, ethical concerns for the safety of patients, and the unavailability of many real-world challenging cases (Rhienmora *et al*., 2010).

As with all health care professions, dentistry is constantly evolving. For dentistry, the irreversible nature of most operative procedures means students must have the skills for safe delivery at the point of patient treatment and care (Perry *et al*., 2015).

In order to enable a smooth transition from preclinical training to the clinical practice for the students (Hanson 2011; Hanson *et al*., 2006, in Zafar *et al*., 2021), simulation training is considered an essential step towards successful patient management. It is important that students receive sufficient preclinical training before they treat the actual patient (Mladenovic *et al*., 2019 in Zafar *et al*., 2021).

The development of these skills requires mastery of two components: knowledge of the concepts of the procedure and the dexterity to perform it **(**LeBlanc *et al*., 2004). Theoretical knowledge of the concepts and techniques can be offered by faculty in large group sessions. However, the performance component requires a situation in which students can repeatedly practice the application of the knowledge imparted by the instructor (Kaufmann, 2001 in LeBlanc *et al*., 2004).

In a dental curriculum, preclinical training offers students the opportunity to develop manual dexterity and master various clinical procedures before treating real patients in a clinic. However, since the conventional preclinical training methods are fraught with several limitations, alternatives were introduced in the late 1990s owing to their potential to complement these conventional methods (de Boer *et al*., 2017). This mainly entailed utilisation of technology in all aspects of instruction. Learning is the process that takes place from the student's perspective as a result of instructional strategies. One of the main areas of IT application in relation to dental education was Simulations (Web-based or not), Simulation of skills, decision making, authentic scenarios, virtual patients, etc. (Mattheos *et al*., 2008).

Significance of digitisation in preclinical training

The realization that the clinical setting is not an ideal environment for skills training, coupled with recent technological advances, led to an increased use of computer applications in health care education. Growth in computer-aided instruction was fuelled by increases in computer capacities, software applicability and accessibility, decreased costs, as well as student demands for the most up-to-date training possible **(**LeBlanc *et al*., 2004). Computer-aided instruction ranges from computer or web-based tutorials, discussion groups, and courses to more sophisticated virtual reality-based, computerized patient simulators and virtual reality-based simulations (Buchanan, 2001 in LeBlanc *et al*., 2004). Simulators were considered useful learning tools as they allowed for practice in controlled environments, were adaptable to flexible scheduling for students as well as instructors, offered an arena for students to test and observe the results of dental procedures without any patient morbidity, facilitated repetition of the skill to be learned, offered controlled training variations, and provided opportunities to quantitatively assess student performance. Students could thus learn how to deal with the outcomes of their actions in safe environments (Miller, 1997 in LeBlanc *et al*., 2004).

McGleenon and Morrison (2021), in their scoping review of methods and trends in undergraduate clinical skills teaching in the UK and Ireland have reported that clinical experience was gained by students mainly in multi-disciplinary clinics and offsite outreach teaching centres because insufficient numbers of suitable patients, increasing student numbers and a fall in teaching staff contributed to a reported reduction in clinical experience of certain treatments. This highlighted the importance of exhaustive and varied preclinical training.

Just as society is changing, our education methods cannot remain static but must be dynamic (Mattheos *et al*., 2008). Just as there is a need to be aware of oral health care needs of the community, educators also need to be responsive to the current trends in technology for improving pedagogy. The implementation of digital technologies in dental curricula has started globally and reached varying levels of penetration depending on local resources and demands.

Overall, digitalization seems to have had a major impact on dental education, addressing various aspects such as e-learning and Web-based knowledge transfer, diagnostics using 3D imaging and digital radiography, and practically oriented trainings in terms of dental simulator motor skills including IOS with 3D printing, prototyping, and digital surface mapping **(**Zitzmann *et al*., 2020).

In particular, digital software tools can be used in the field of motor skills training to evaluate the manual abilities of potential candidates for the dental curriculum, to analyze students' preclinical preparations, to enable self-assessment, and to enhance the quality of education. The objective and exact nature of these digital evaluations helps to improve students' visualization, provides immediate feedback, and enhances instructor evaluation and student self-evaluation and self-correction (Miyazono *et al*., 2019; Greany *et al*., 2019 in Zitzmann *et al*., 2020). Students can learn to self-assess their work with self-reflection and faculty guidance in conjunction with a specially designed digital evaluation tool (Garrett *et al*., 2015 in Zitzmann *et al*., 2020).

Digital dentistry is the new pedagogical paradigm that offers multiple advantages over conventional dental teaching methods (Zafar *et al*., 2020). Digital innovations including virtual reality (VR) and augmented reality (AR) are becoming more prevalent in dentistry (Dutã *et al*., 2011 in Zafar *et al*., 2020).

Technology assisted preclinical instructional methodologies

Providing fluent transition of clinical skills from preclinical level into dental clinics is a major concern amongst dental educators, for which various effective and valid tools have been developed (Khalifah, 2020). Due to the developments and progress of the "digital revolution", many innovations to support new teaching concepts are observed in dental education (Hugger, 2011 in Hanisch *et al*., 2020).

Mattheos *et al*. (2008) stated that there are many newer methods for acquisition of skills (preclinical and clinical) such as: Simulations, which could be two or three-dimensional (visual and more realistic for simulation of skills), decision making simulations (virtual patients) for the improvement of clinical decision-making skills, use of Haptics for feedback, videos for training in anatomy, and surgical techniques.

Computer assisted Simulation

Simulation is defined as a situation in which a particular set of conditions is created artificially in order to study or experience something that could exist in reality (Mladenovic, 2020). Maliha *et al*., in 2018 defined simulator as a ''device that uses simulation to replace a real-world system or apparatus, allowing users to gain experience and to observe and interact with the simulation via realistic visual, auditory, or tactile cues.''

Simulation has been utilised in dental education since dental students are expected to achieve an acceptable level of competence at the preclinical level before their clinical training. This is important since most procedures on teeth (such as cavity preparation, endodontic therapy, and orally surgical interventions) are irreversible, and learning these skills solely on patients is not an acceptable practice (Levine *et al*., 2009 in Mladenovic, 2020). Simulation allows students to repeat procedures till they are able to demonstrate the required skill level without putting actual patients at risk, and acquire procedural competence. Thus, most psychomotor skills are first taught in a simulated manner before students engage in patient management (Dutã *et al*., 2011 in Mladenovic, 2020).

Nassar & Tekian (2020) stated that Simulation-based dental education (SBDE) is an emerging component in undergraduate dental education in general and in operative applications in particular. They observed that Computer assisted simulation was found to be beneficial to students' learning and training in operative dentistry, as it allowed magnification and viewing of student's work from multiple angles, provided real-time feedback by special computer software to allow for training sessions without the need for instructors' presence and allowed consistent and standardized evaluation. Additionally, the training sessions could be recorded for later viewing to provide individualized assessment and feedback.

Zitzmann *et al*. (2020) also reported a high level of interest and acceptance among undergraduate students for Computer assisted simulator training in cavity preparations or in surgical interventions such as apicoectomies. They reported a trend towards improved technical skills and ergonomics when simulator training with real-time feedback was added to traditional instructions.

Simulated learning environments in dentistry employ a wide range of activities and experiences that allow students to refine clinical skills in a preclinical setting. The traditional methods are well established however, they have disadvantages including the consumption of materials, availability of qualified staff for supervision, significant operational expenditure relating to maintenance and infection control protocols and large upfront costs (Zafar *et al*., 2020). On the other hand, while Computer assisted learning environments such as Simodont® also involve an upfront cost including a server and teacher station computer, there is no consumption of materials and students may still benefit from simulation-assisted learning with a smaller staff-to-student ratio, or with automated feedback provided by the Simodont® (Zafar *et al*., 2020).

Similarly, LeBlanc *et al*. in 2004 investigated whether training with a computerized simulator was comparable to or better than traditional training in developing the skills necessary for performing operative dentistry procedures. They used DentSim® computer-assisted simulator manufactured by DenX Ltd., Israel, which is a clinical simulator providing real-time tactile feedback with use of 3D graphics and real time image processing. They concluded that 'while the use of simulators for the training of dental students holds promise, their integration into the curriculum should not go unchecked. Rather, the implementation of simulators should be guided by theory and by relevant research regarding how individuals obtain and process information. For this last purpose, simulators can serve the additional function of aiding researchers in determining areas of clinical practice that need enhancement and of guiding faculty in modifying curricula'.

3D printing technology

Lambrecht *et al*. developed surgical training models in 2010 based on real patient data and fabricated them by 3D printing (Hanisch *et al*., 2020). Since then, rapid advances in 3D printing technologies have allowed more and more educators to produce their own training models. By combining highly precise intraoral scanning, computer-aided design and high precision 3D printing, realistic models based on real patient data can be created, with the ability to constantly vary the training scenarios. With the conventional, over-the-shelf typodont models it was not possible to simulate individual anatomical situations. With the 3D-printed models, which can be produced cost-effectively in small quantities, it is now feasible to produce a training model even for a specific real surgical situation. Such a model could be used by less experienced surgeons to train in surgery before performing it on the patient (Hanisch *et al*., 2020).

In recent years, a start has already been made to introduce individualized surgical training models (Lambrecht *et al*., 2010; Werz *et al*., 2018 in Hanisch *et al*., 2020). Hanisch *et al*. (2020) reported that individual 3D-printed surgical training models based on real patient data offer a more realistic alternative to industrially manufactured typodont models, and thus they are convinced that Haptic models will continue to be indispensable in the education, training and examining of dentistry students in the future.

Zitzmann *et al*., in 2020 emphasised that 3D education programs have been introduced to enhance students' spatial ability, their interactivity, critical thinking, and clinical correlations with the integration of multiple dental disciplines. Augmented reality in 3D visualization allows insights in tooth morphology, and also facilitates treatment planning with fixed or removable partial denture (RPD) programs (Goodacre, 2018 in Zitzmann *et al*., 2020). Digital technologies also include the 3D printing of virtual teeth, which has been suggested to enhance transparency for all students due to the identical setups (De Boer, 2018 in Zitzmann *et al*., 2020). Hanisch *et al*. (2020) summarised that there are very promising approaches for the use of 3D-printed models in dental education.

Virtual teeth

De Boer *et al*. (2013) evaluated the accuracy and precision of non-clinical testing of dental students' proficiency in crown preparation on a typodont. Their analysis showed that performance on typodonts is a poor predictor of clinical performance on patients. Experience has shown that in many countries, the number of suitable extracted teeth available for dental education is insufficient. In most dental schools, extracted teeth must be sterilised before use, which may cause potential hazards and negatively affect their quality. Plastic teeth look and feel very different from natural extracted teeth and usually have no simulated pathology, and those that do exhibit some pathology are very expensive (Dominici, 2001 in de Boer *et al*., 2013). Furthermore, typodonts may easily become contaminated, putting students and teachers with airway problems at risk (Aycock & Hill, 2009 in de Boer *et al*., 2013).

Virtual teeth in a virtual learning environment can offer many solutions and opportunities in dental education. For example, pre-surgical practice in a virtual environment using a 3D model of a virtual tooth generated from an original CBCT was shown to improve endodontic microsurgery performance (Suebnukarn, 2010 in de Boer *et al*., 2013). The availability of virtual teeth is unlimited, they can be more realistic than plastic teeth and can display any type of dental pathology for a virtual patient case. Additionally, there are no costs for the students as there are with plastic teeth, and they are safe to work with in terms of hygiene and patient safety.

Virtual teeth can be used in a simulation learning environment, such as the haptic dental trainers Simodont, PerioSimTM (University of Illinois, Chicago, USA) or hapTELTM (Kings College London, University of London, UK). When a virtual tooth is cut, visual, audio and tactile feedback is received simultaneously. 'Haptic' means relating to or proceeding from the sense of touch (Suebnukarn, 2009 in de Boer *et al*., 2013). The amount of force feedback received depends on the dental tissue being 'treated'; enamel feels harder than carious tissue. A 3D view is created using special glasses. A separate computer connected via an interface to the training console contains the lesson program for the students (i.e. the courseware). The courseware contains a 'waiting room' of virtual patients with virtual teeth and manual dexterity assignments. (de Boer *et al*., 2013).

De Boer *et al*. (2013) explained that the creation of virtual teeth with and without pathology offers many opportunities and advantages for dental education in terms of safety, cost and usability. This enables the students to work on a variety of pathologies in virtual teeth and even to develop complete patient settings with varying degrees of complexities, allowing dental students to develop competencies and skills that would otherwise require patients or extracted teeth, which may not be sufficiently available in many dental schools.

Virtual Reality

Al Mussawi & Farid in 2016 stated that virtual reality (VR) technology is defined as a method by which, an environment is three dimensionally simulated or replicated, giving the user a sense of being inside it, controlling it, and personally interacting with it, and that the virtual environments are almost completely generated by computers. They further explained the features of VR, stating that virtual reality depends on two basic features namely, immersion and interaction. Immersion is the sense of being present in a virtual (non-real) environment. The environment is generated by synthesizing 3D images, sound and other stimuli, which surround the users and make them feel like being physically present in a nonphysical (non-real) world. The degree to which the user believes being present in a virtual environment (immersion) is different in various systems ranging from fully immersive to nonimmersive, depending on the capabilities of the system (Mujber *et* *al*., 2004 in Al Mussawi & Farid, 2016). Interaction is the power of the user to modify the virtual environment (Ryan, 1999 in Mussawi & Farid, 2016). In VR systems, the user is able to interact with the virtual world, moving around it, seeing it from different angles, reaching it, grabbing it and reshaping it.

Alauddin *et al*. (2021) described Virtual Reality (VR) as the total immersion of a user in composite virtual environments in which the user's feelings, senses, and reactions are virtually simulated by the computer, thus, creating an artificial interaction.

Currently, within dental education, virtual reality (VR) is used as an umbrella term to describe a number of technologies, from full three dimensional (3D) headsets that immerse the user in a virtual world, to systems that perform automated assessment of students performing cavity preparations on enhanced phantom heads equipped with stereoscopic cameras **(**Towers *et al*., 2019). The adoption of VR has been driven by limitations of traditional approaches in finding real world cases, lack of availability of tutor time, limitations of plastic teeth to simulate realistic experiences, and the subjectivity of assessment (Xia *et al*., 2013 in Towers *et al*., 2019).

Virtual reality workstations have been developed as an alternative to the conventional phantom head units for pre-clinical skills training in a small number of dental schools.

Reported advantages were a reduction in required supervision, the potential to increase work rate compared to traditional supervisor-led classes and a reduction in running costs. (McGleenon & Morison, 2021).

In recent years, technological advances have made it possible to incorporate Virtual Reality (VR) simulation technology into preclinical dental education (Mladenovic, 2020). Virtual reality simulators provide the ability to integrate clinical scenarios into the operating environment and facilitate tactile skills using haptic technology (Dutã *et al*., 2011 in Mladenovic, 2020). Haptics is a tactile feedback technology that takes advantage of users' sense of touch by applying force, vibrations, or motion to the user.

There are two types of computerized virtual reality simulators available: mannequin-based simulators on which certain dental procedures can be performed using real dental instruments (DentSim, DentX, Israel) and haptic-based simulators that employ an haptic device and virtual models as a platform to facilitate dental training (Simodont Dental trainer, Nissin, Netherland). Simodont provides a virtual environment to practice various dental skills in virtual oral and dental environment. The system also produces convincing visual and audio effects during performance to enhance the simulation experience and make it more realistic (Cutler *et al*., 2013 in Mladenovic, 2020).

At its simplest, VR systems provide an artificial environment that users can experience through sensory stimuli provided by a computer or a VR simulator, wherein the occurrences are partly determined by the user's actions (de Boer *et al*., 2017). The realism of VR training is increased by the use of haptics, which provide the user with tactile sensations through a process known as force feedback (FFB) (Rhienmora *et al*., 2010 in de Boer *et al*., 2017; Murbay *et al*., 2020). The FFB allows a learner to obtain the feel of an invasive procedure in a virtual learning environment (VLE). The use of haptic technology is particularly advantageous in the field of dentistry because the development of psychomotor and contact-mediated tactile skills is a major part of training (Eve *et al*., 2014 in de Boer *et al*., 2017). Haptics can distinguish between expert and novice performances in complex haptic procedures (Urbankova *et al*., 2013 in de Boer *et al*., 2017).

The advantages of VR simulators are that the procedures can be practised as many times as needed, at no incremental cost and that the training can take place anywhere. The realism of these simulators has increased with the introduction of haptic devices that provide tactile sensations to the users (Rhienmora *et al*., 2010). Additionally, Virtual reality simulators have proved their feasibility in diagnosis, obtaining objective and immediate evaluation and developing critical thinking (Khalifah, 2020). As reported by Zitzmann *et al*. (2020), preparation performance on VR units with continuous evaluations and advice from clinical instructors led to better preparation quality than real-time feedback from the virtual dental unit. Self-paced learning and the immediate software feedback were beneficial with the VR unit, and it was perceived as adjunct, but not replacing faculty instructions (Quinn *et al*., 2003 in Zitzmann *et al*., 2020).

Virtual reality based training tools have been recently introduced into the dental education (Hanson, 2011 in Zafar *et al*., 2021). Such educational tools provide 3D (three dimensional) learning settings that are close to a real sense of interaction, so enhance clinical learning of dental students (Correa *et al*., 2017 in Zafar *et al*., 2021). Further, a VR setting enables the students to differentiate intraoral anatomical structures that are considered critical elements in obtaining clinical skills to deliver LA due to the three-dimensional nature of the setup (Hanson 2011; Hanson *et al*., 2006 in Zafar *et al*., 2021).

Other benefits provided by VR include trial and error as students can practice several times before dealing with real patients, automatic evaluations of performance and repeated training in a controlled environment, and they can also can pause and review their account at any stage and seek guidance. (Correa *et al*., 2017 in Zafar *et al*., 2021).

The growth in the use of VR simulators may be related to the benefits provided by them, such as: they reduce risks, prevent 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 (Corrêa *et al*., 2017).

Dental skill training with a VR simulator provides a new opportunity that is difficult to realize otherwise: objective assessment of surgical competency. Skill assessment is usually conducted by having instructor observe the procedure or only the final outcome. However, the level of detail of human expert assessment is limited. With VR simulators, every aspect of the operator's work can be collected during the simulation and analyzed further to provide a fine-grained objective assessment (Rhienmora *et al*., 2010).

Augmented Reality

Augmented reality (AR) is defined as an interactive development of technology utilizing additional, composite animated information in the user's real world. AR effectively enhances the user's real life in the real world through virtual simulation of live imagery and videos (Huang *et al*., 2018 in Allauddin *et al*., 2021). Augmented Reality (AR) is a simulation of a three-dimensional environment created using hardware and software that provides the user with realistic experiences and ability to interact (Mladenovic, 2020).

Augmented Reality evolved after Virtual Reality, because it required more complex technological specifications, though it is essentially simpler to realize than Virtual Reality. The reason is that it enhances the existing environment by adding virtual elements, rather than replacing it with a completely new environment. Yet, it encounters real-world dynamics that are generally difficult to control and often unpredictable (Bugaric, 2013 in Mladenovic, 2020).

Al-Mussawi & Farid, in 2016 enumerated the applications of AR in preclinical dental training, which include: learning dental morphology, administering local anaesthesia, maxillofacial surgery, dental implantology, aesthetic dentistry and restorative dentistry.

The benefits of AR technology in dental education are that as educational tools, AR simulators can provide enhanced opportunities for students. An AR system can facilitate versatility in the learning process, as learning activities can be performed anywhere and at any time without supervision. However, there are some limitations to the use of AR. Most are expected to be overcome by technological advances. It seems that work with other technologies may enhance the function of existing AR systems (Schnelzer *et al*., 2012; Diana *et al*., 2014, in Mladenovic, 2020).

Application of AR technology can be of great benefit to students transitioning from the preclinical level to clinical practice or mastering more demanding dental procedures. This new technology provides access to educational resources, quality interaction, and lowered the cost of the overall training.

Difference between Augmented reality and Virtual reality

The concepts of Augmented Reality and Virtual Reality are frequently confused with one another due to the similarities in their names and functions. The difference is primarily in the technology used (Mladenovic, 2020). Virtual Reality attempts to create an artificial world that a person can experience and explore interactively, through his or her senses, whereas Augmented Reality also brings about an interactive experience, but aims to supplement the real world, rather than creating an entirely artificial environment (Höllerer & Fiener, 2004 in Mladenovic, 2020).

Both systems and techniques are implemented through the user's sensations either individually or in a combination of all haptic, hearing, auditory, and motor sensations (Alauddin *et al*., 2021). There is a plethora of applications and software which are greatly supported by this technique to enhance the ability and capacity of dental practitioners and dental specialists in providing a total patient care system (Huang *et al*., 2018 in Alauddin *et al*, 2021). Joda *et al*. (2019) mentioned that one of the biggest confusions in the area of simulation technology is the differentiation between augmented reality (AR) and virtual reality (VR): AR is a technology that superimposes a computer-generated virtual scenario atop an existing reality in order to create a sensory perception through the ability to interact with it. In contrast, VR is an artificial computer-generated simulation of a real life environment or situation. It immerses the user by making them feel like experiencing the simulated reality first hand, primarily by stimulation of vision and audience in real-time (Huang *et al.*, 2018).

A recent review on the application of AR and VR in dental medicine by Zitzmann *et al.*, in 2020 demonstrated that the use of AR/VR technologies for educational motor skill training and clinical testing of maxillofacial surgical protocols is increasing. They concluded that these digital technologies were valuable in dental undergraduate and postgraduate education, offering interactive learning concepts with 24/7 access and objective evaluation. A recent scoping review analyzed the application of VR in preclinical dental education and identified four educational thematic areas (simulation hardware, realism of simulation, scoring systems, and validation), highlighting the need for a better evidence base for the utility of VR in dental education (Towers *et al*, 2019 in Zitzmann *et al*, 2020).

Dental education also promises another platform for advancement of the AR/VR system (Alauddin *et al.*, 2021). Theoretical knowledge often delivered based on a traditional classroom environment during the undergraduate dental studies can be further enhanced during the practical skill sessions (Roy *et al*, 2017). This allows not only a receptive feedback environment, but also an interactive teaching space with room for objective and numerical evaluation. The systems will inadvertently improve simulated prospective preclinical training, hand-eye coordination, and ergonomics without the risk of harming a real-life patient (Towers *et al*., 2019). Such systems will also allow dental students to reflect and learn by themselves, thus decreasing the faculty workload as compared to traditional preclinical simulation training.

Virtual Patients

A Virtual Patient (VP) is recognized in the context of medical education as: 'An interactive computer simulation of a real-life clinical scenario for the purpose of teaching, learning and assessment' (Marei, 2018).

American Association of Medical Colleges (AAMC) describes a VP as 'A specific type of computer-based program that simulates real-life clinical scenarios; learners emulate the roles of health care providers to obtain a history, conduct a physical exam, and make diagnostic and therapeutic decisions' (AAMC, 2007, p7, in Marei, 2018). According to Antoniou *et al*., 2014, Virtual patients have been defined as 'interactive computer simulations of real-life clinical scenarios for the purpose of medical training, education, or assessment.'

A virtual patient (VP) is an interactive computer-based patient case simulation for healthcare education. Initial VPs were electronic versions of their paper-based counter-parts but with a significant upgrade in technology and pedagogy, successful web-based learning environments have been developed (Zary *et al*., 2012).

Marei, in 2018, explained that the VP is a clinical scenario that plays on a computer screen. In general, in using a VP, learners read or listen to the virtual patient's complain (on the screen) and request specific investigations (such as radiographs or lab tests) by selecting options from a drop-list or by entering text. Upon presenting the results of the requested investigations, learners are requested to interpret the findings and select from a list the most likely diagnosis and then suggest the most appropriate treatment plan. Within this general description of a VP, there is a wide room for variation in its design, use, and integration within a curriculum.

In all VP designs, learners invariably interact with the VP by either selecting from a list of options or entering free text. The learner can follow the consequences of the decision taken as in branching-tree design, or directly be guided to the next stage as in linear active design. Moreover, VPs can be programmed to provide immediate formative feedback as per the learners' choices, or it can generate a summative report at the end of the session (Huwendiek *et al*., 2009 in Marei, 2018).

There is a general agreement on the importance of designing VPs that (a) target relevant real-life problems, (b) are highly interactive, (c) are of an appropriate level of difficulty, (d) involve an authentic interface that reflects the reality of clinical practice and provides feedback to the learner, and (e) shows the consequences of the decision taken during VP practice (e.g., actual clinical evolution and the effect of offered treatment through the case). Finally, a student's persistent engagement with VPs depends on the balance between presenting data (reading a history, getting test results) and telling a story (engaging in conversation, character, and narrative) (Marei, 2018).

The advantages of using VPs is that it can offer a solution to the common dilemma of students' limited access to real patients (Ellaway *et al*., 2008; Johnson *et al*., 2014, in Marei, 2018), which could be due to a real shortage in the number of patients or inability of students to access clinics in the most appropriate phase of their educational program. Finally, most healthcare systems prioritize patients' clinical service above students' clinical training. Therefore, curriculum designers can use VPs to link basic sciences and clinical training, by incorporating VPs within teaching sessions of basic sciences to show the relevance of basic concepts to clinical problems (Marei, 2018).

MultiUser Virtual environment

Since their inception, virtual patients have provided health care educators with a way to engage learners in an experience simulating the clinician's environment without danger to learners and patients which has led this learning modality to be accepted as an essential component of medical education. With the advent of the visually and audio-rich 3-dimensional multi-user virtual environment (MUVE), a new deployment platform has emerged for educational content. Immersive, highly interactive, multimedia-rich, MUVEs that seamlessly foster collaboration provide a new hotbed for the deployment of medical education content (Antoniou *et al*., 2014).

Dental educators can also use virtual worlds in order to create clinical scenarios, to allow students to interact with virtual patients and practice in diagnosis and treatment planning (Papadopoulos *et al*., 2013). There are some interesting examples of dental education applications in virtual worlds, for eg, the virtual building at a dental school could have a specialty focussed area, or interactive dental units for role play (Papadopoulos *et al*., 2013).

According to Bell (2008) in Papadopoulos *et al*., 2013, a virtual world is a synchronous, persistent network of people, represented as avatars, facilitated by networked computers. By "persistent", it is implied that this virtual world, along with the changes the users make, continue to exist and evolve while the user is offline. The users of a virtual world take the form of an avatar, which is the "alter ego" of a human being that is usually represented by a 3D humanoid model.

Need to empower the facilitators?

Zitzmann *et al*. (2020) observed that while undergraduate students today have to be prepared for digital dentistry, they still need to acquire the knowledge of conventional treatment strategies and processes. Growing up in the digital world, they will easily adapt to digital features. Digital dentistry offers several options for an objective standardized evaluation of students' performance, which should be used for quality enhancement.

It is currently a "teaching transition time", and new standards have to be defined for dental education in general. Several studies indicated that personal instruction and feedback from faculty cannot be replaced by simulator training and feedback (Kozarovska & Larsson, 2018; Ren *et al*., 2017 in Zitzmann *et al*., 2020).

In this context, faculty should be aware of their responsibility in teaching young dentists, who are treating individuals with individual needs requiring empathy and an informed consent for any treatment decision. Digitalization cannot replace all educational lessons or courses, and the role-model function of faculty is important when supervising students during patient treatment in the clinical courses (Zitzmann *et al*., 2020).

Mattheos *et al*. (2008) observed that many members of faculty are not comfortable using new technology and they should be provided support to encourage them to effectively use technology to its fullest extent. They stated that it could be achieved through faculty knowledgeable/comfortable with technology to serve as mentors to their colleagues. Where possible, institutions should appoint an e-learning champion with good interpersonal skills to support and encourage faculty change.

Khalifah (2020) has summarised that dental skills transferability is affected by interaction of several factors which affect one another. However, virtual reality simulators have proved their feasibility in diagnosis, obtaining objective and immediate evaluation and developing critical thinking. On the other hand, interactive and internet based simulations have proved their efficiency in remote learning, promoting information retention in students' memories, providing new scopes in courseware development, and enhancing the understanding of some theoretical aspects of dentistry. Finally, conventional simulation in mastering dental manual practicing process and their role in acquisition of clinical skills still remains valid until new technology and business world can create alternative tools. He has offered few suggestions for providing effective technology based simulation, as follows:

i. Dental students should learn the composition and the application of simulation devices, so they will be exposed to them prior to starting actual practice.

ii. Integrating multidisciplinary interactive multimedia simulation in preclinical courses to enhance students' comprehension and understanding of the real nature of clinical work.

iii. Teaching problem-based learning strategies by adding interactive multimedia programs that represent real patient cases simulation; this could be done by allocating these programs within the diagnosis part of each dental specialty, e.g., endodontics, dental surgery, operative dentistry, etc.

CONCLUSION

There has been a shift towards embedding digital dentistry into the curriculum, and the current technology could enhance students' learning experience. Dental schools and universities should be more prepared in investing their time and effort in the development of similar dental technologies to ensure safety and training of dental student's post-COVID-19 pandemic (Zafar *et al*., 2021).

Zitzmann *et al*. (2020) have emphasised that there are still no uniform standards in dental education with regard to the digital tools applied. Such standards are essential to ensure uniformity in teaching, which is particularly important for an international exchange. Society as well as dentistry is currently undergoing a digital transformation. It is necessary to clarify learning contents, to what extent conventional workflows should still be taught, and what can be done digitally. While digital tools and applications in knowledge transfer are a general challenge for undergraduate education in all disciplines, the field of dentistry with its high degree of practical training units is specifically demanding. Just because training units are designed digitally does not mean that students learn on their own. Continuous training with supervision and feed-back is still the key to good dental education. In this context, digitization is certainly a great opportunity to convey the learning content with more joy and newly awakened enthusiasm.

Zitzmann *et al*. (2020) further highlighted that by following the rule: "you can only teach what you are able to perform yourself", a highly motivated faculty is needed that is willing to embrace the latest digital technologies. Besides personal motivation, the financial aspect of implementing the various digital tools and applications has to be managed at dental universities. Collaborations with industry would be beneficial in such situations. They further concluded that in future, the best dental schools will be ranked according to their digital infrastructure, combined with the level of innovations by the teaching faculty.

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