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Education and learning in digital dentistry

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Abstract

Digital dentistry includes a wide range of technologies that bring communication, documentation, production and distribution under the umbrella of computer-based algorithms in dental treatments. It also plays an important role in shaping innovation and student experience in dentistry education. Since learning methods and tools continue to advance, an understanding of educational methodologies themselves, as well as those who use them to teach and learn, is crucial to optimizing educational effectiveness. In undergraduate dental laboratory training, digital simulation technologies have already been implemented to dental faculties and their curriculums in several countries. These simulation technologies include digital microscopes, virtual pathology slides, digital X-ray images, digital dental skill training machines, digital assessment systems, and robot patients. In this article an overview to the digital dentistry education was reported.

Keywords: digital dentistry, dental education, digital preclinical education, digital simulation technologies

1. Introduction

Generation Y (millennium generation) is the expression used to describe a person who generally reached adulthood in the early 21st century and was born in the period of the early 1980s to the early 2000s (Jackson et al., 2018). Most dental students belong to the millennial generation came to the campus in 2000 (Blue and Henson, 2015). This generation, born in the age of rapid technological advancements and has different features that may require former educators to adapt their teaching strategies to the most effective way (Turner et al., 2016; Jackson et al., 2018). Their unique characteristics, diversities and expectations for the learning environment are challenging the faculties to reconsider their traditional pedagogy as well as the learning environments offered to students (Blue and Henson, 2015).

Technology is perhaps the most distinctive feature of the Millennial generation. Because of personal computers are indispensable for this generation and are always with them, this generation awaits an environment enriched with multimedia in the classroom. Interestingly, professors using multimedia (YouTube, movie clips, etc.) saw better student test scores in quizzes and examinations (Wilson and Gerber, 2008; Blue and Henson, 2015). Technology allows Millenails in constant contact with each other and the world around them, and blurs the lines between work and life (Blue and Henson, 2015).

In addition, the use of technology can allow direct observation of students' studying habits and generate objective data to help optimize and personalize dental education. (Jackson et al., 2011; Jackson et al., 2018). It is important that the faculty "frames" the course and supports student interactions by providing resources and opportunities. In addition, the faculty should develop a conceptual rationale for incorporating technology into its teaching and determining how it fits into teaching and learning philosophies. In other words, technology should only be used if it improves teaching and learning, not for its own sake (Blue and Henson, 2015).

2. What is digital dentistry?

Digital technologies have gained great importance in recent years and play an important role in the development of dentistry. Today, in dentistry applications; communication and access to information are increasingly computer-aided, digital radiology and photography have become widespread in diagnosis, and dental treatments are mostly based on digital methods for processes such as impression taking, treatment planning and implant surgery (van der Zande et al., 2013).

The spread of digital technologies in dentistry began in the early 1990s with the introduction of digital radiography, and the first versions of intraoral scanning and computer-assisted design, computer-assisted manufacturing (CAD/CAM) crowns. With the development of cone-beam computed tomography (CBCT), the three-dimensional images of the

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craniofacial region became the precursor of a second wave of excitement as it offered new advantages in diagnosis and treatment. When improvements in hardware, software and materials were combined in the early 2000s, new successes in clinical dentistry were realized. Same-day, chairside restorations of remarkable dimensional and esthetic fidelity were obtainable. Guided implant surgeries provided enhanced therapeutic workflow and safety (Cooper, 2019).

3. Digital dentistry education

Today, technology is playing an important role in driving innovation and shaping student experience in dentistry education. As learning methods and tools continue to advance understanding educational methodologies is crucial to optimizing educational effectiveness, (Jackson et al., 2018). Innovations such as virtual anatomy, haptic feedback tools, and improved digital charting methods offer many opportunities to make pre-clinical education more efficient. In restorative dentistry and prosthodontics, digital assessment tools allow students to evaluate their performance in real-time without direct supervision. Digital communication tools in clinics provide remote supervision or advanced local management of supervision. In addition to these advantages, digital technology poses significant challenges for curriculum management, and the overlap of analog and digital educational objectives requires adaptation. In addition, if digital technology is adopted in restorative and prosthodontics education, most of the dental stones, waxes, casting alloys and traditional dental materials will not be used and the value of traditional dental materials will decrease.

In the age of big data and analytics, perhaps students will need more computer programming knowledge to support evidence-based decision making and to fully discover the information needed, and therefore will need to take computer courses. In this way, digital technology can become an educational goal and desired competence that will replace other parts of the curriculum. Another concern is that students' patient interaction skills may suffer if they interface with technology more than with surrogate patients, faculty, and peers. There is also another concern that students will not develop the manual dexterity required to perform dental procedures at defined competency levels using analog procedures. Finally, as a result of the inability to achieve technological developments in education in low socioeconomic income societies, potential social injustice may arise or increase (Cooper, 2019).

4. Digital simulation technologies in dental education

The use of digital simulation technologies in undergraduate dental laboratory training has already been implemented to their professional curricula in various countries (the United States, Germany, Australia, the UK and China). These simulation technologies include digital microscopes, virtual pathology slides, digital X-ray images, and digital preclinical laboratory training systems and robot patients (Ren et al., 2017).

Digital microscopes

Light microscopy is an analog technology that has been used in dentistry education for a long time, especially in the fields of histology and pathology. The latest technological advances have enabled computers to turn into microscopes, making the transition from light microscopy to digital microscopy (DM). DM is a technology that uses the computer to analyze a slide specimen. Following traditional slide preparation, slides are digitally scanned at a high resolution, making the sample suitable for computer analysis and interpretation (Farah and Maybury, 2009; McCready and Jham, 2013).

Recent studies have shown that DM has become increasingly important in many academic fields due to its popularity among students and logistical advantages. In studies where DM and traditional light microscopy were used simultaneously, students have repeatedly shown a preference for the use of DM. Students also reported that DM improved their oral and maxillofacial pathology learning positively and had a higher educational value even when the resolution and quality of the images were similar to their light microscopy counterparts (Weaker and Herbert, 2009; Szymas and Lundin, 2011; McCready and Jham, 2013).

Virtual pathology slides

Virtual pathology slides are high-resolution scanned images of glass microscope slides that can be viewed using an Internet browser (Fred and Dee, 2009). Students can analyze and interpret slides on the computer, and it means that virtual slides can be accessed at anytime from anywhere, without the risk of slide breakage or loss (Farah and Maybury, 2009; Ren et al., 2017).

This training model allowed educators to label virtual slides with arrows, circles, and text labels. Integration with a database structure allowed educators to easily link descriptive text specific to virtual slide in a separate browser window and create links to additional gross images and normal virtual slides (Fred and Dee, 2009).

Digital X-ray images

Dental digital radiographic images contain all non-film based methodologies and are often referred to as computed dental radiography, direct dental radiography or simply digital radiography (Mauriello and Platin, 2001). Digital radiography includes digital sensors instead of photographic film, which eliminates the need for chemical processing, enables the images to be transferred and enhanced digitally, and reduces the amount of radiation required. Today, digital X-ray images are widely used in dentistry education to teach oral radiographic anatomy and image interpretation (Vuchkova et al., 2012; Ren et al., 2017). According to the results of the study of Vuchkova et al. (2012) the digital method positively affected the learning process by providing the students to better interact with course material when compared to textbooks. They stated that this would be related to the students' intrinsic motivation for computer-based learning. In addition, students interpreted the use of digital methods as "interesting", "fun" and "not as boring as the textbook”. As a result, they concluded that digital method is not quantitatively superior to conventional textbooks in assisting dental students, but there has been a strong preference for the digital tools as a source of learning and teaching in radiographic interpretation (Vuchkova et al., 2012).

Digital preclinical laboratory education

Simulation is a vital part of the learning of restorative dentistry. It provides the student with motor and procedural information that is otherwise impossible to learn. It is a way of ensuring patient safety while transferring those learned skills to clinical patient care. Dental training programs use simulation in a variety of ways to prepare the student for clinical activity. Basic restorative preclinical training generally focuses on standardized cavity preparation and restoration in teeth set in 'phantom heads' (Fugill, 2013).

Traditionally, mannequins have been used for clinical skill training, but the model is quite different from a real patient because it has no autonomous movement or speaking ability. This indicates that this kind of pre-clinical simulation training is inadequate (Tanzawa et al., 2012). The main disadvantages identified in the use of mannequins are:

i) lack of clinical reality,

ii) lack of testing communication skills,

iii) lack of patient management / behavior problems (Mossey et al., 2001).

Such practice sessions are supervised by clinical tutors, providing oral feedback to the students. The effectiveness of such sessions depends on the teacher’s abilities and the number of tutors available to provide frequent feedback to assess students’ learning progression (de Peralta et al., 2017). In order to overcome these deficiencies, simulations using advanced technology in recent years have come to the fore in the field of dentistry (Buchanan, 2001; Imber et al., 2003, Wierinck et al., 2007). The use of simulation training has become an integral part of dental education and has been practiced in dental schools throughout the world (Roy et al., 2017). Virtual reality simulators (VRS) provide benefits to traditional simulation teaching such as providing unlimited virtual teeth, immediate objective individual feedback, and unlimited user practice while reliably tracking students’ progress (Gal et al., 2011). These simulated models allow instructors to explain and improve on students’ hand-eye coordination and dexterity, but it is difficult to explain the verbal definition of tactile sensation. Simulation exercises including new technologies and haptic (tactile) and virtual laboratory environments have been developed, and these technologies have been reported to increase motor skills and student effectiveness while reducing time spent in faculty. Popular dental VRS systems include the Virtual Reality Dental Training Systems (VRDTS) for caries removal and periodontium measurement, the Iowa Dental Surgical Simulator (IDSS) for caries detection, PerioSim for subgingival calculus detection, and Dental Trainer for cavity preparation (Roy et al., 2017).

Lieberment and Erdelt (2020) investigated the acceptance of preclinical students for learning dental morphologies in VR and stated that the VR dental learning environment led to a much better understanding of the dental morphology by 34.9% of the students and to a better understanding by 57.1%. This illustrates the high acceptance as learning environment by the students, since the teeth can be spatially enlarged and viewed inter-actively. Also, the handling of the controllers and VR head-sets are no obstacle to the students. After a short orientation phase of about 30 seconds, all students were able to move around well in the VR dental learning environment and interact with the objects.

Buchanan stated that when students are trained with VRS, they learn faster, perform more operations per hour, gain the same level of proficiency as traditional pre-clinical laboratories, and request more evaluation on the computer, thereby shortening the teacher-student evaluation period (Buchanan, 2004).

Blended learning designs in the form of virtual reality provide instant feedback between the student and the educator, ensuring that the time spent in the laboratory is completely productive. Since the student has developed his/her fine motor skills sufficiently, he/she can safely switch move into clinical practice (Roy et al., 2017). Virtual designs allow preparations to be displayed in many ways and at various magnification rates controlled by the operator. This can enable students to understand the design and preparation of the cavity critically by themselves (Robinson et al., 2001). At the same time, the virtual mouth and the image of the tooth provide feedback on the real-time spent on the tooth analogue during the tooth preparation. The ability to record and replay individual applications is an encouraging development for this technique (Norman and Schmidt, 1992).

The HapTEL project is part of the Technology-Enhanced Learning Programme jointly funded by the UK Economic and Social Research Council and the UK Engineering and Physical Sciences Research Council (Arevalo et al., 2013). Ria et al. (2018) tested a scoring system to assess the learning progression of novice dental students using haptic virtual workstations. They found that the HapTEL VRS system usage improved the students’ performance on simulated cavity preparation after practicing over two sessions.

Digital preparation assistant systems have been introduced in the last few years to improve students' learning process. In these systems, such as the PREPassist system (Kavo, Germany), students can evaluate the quality of their preparations using a computer. The system creates visualizations of different preparations of resin teeth using a CCD camera. Using this system may lead to more effective, more objective and ultimately more efficient learning of operative skills (Kournetas et al., 2004).

In recent years, especially in Japan, robotic simulated patients with the ability to move independently, secrete saliva and limited talk with the trainee has been introduced (Eaton et al., 2008; Tanzawa et al. 2012). The reasons for producing robot patients are: (i) to reproduce the oral maxillofacial anatomy for dental treatment; (ii) the whole body can be presented; (iii) autonomous movement can be produced via the robotic system; and (iv) to enable conversation with the trainee (Tanzawa et al., 2012).

5. Conclusion

In today's dentistry education, digital microscopes, virtual pathology slides, digital radiography and chairside applications of restorative and prosthetic procedures have strengthened their position, while virtual reality, haptic-enhanced VR simulations and robot patients used in pre-clinical laboratory education systems are still in the initial stage and increasing interest in their future development is apparent. Many research questions still need to be answered to accept these technological advancements more broadly in dentistry education. Expansion of software to increase the number of dental procedures available would also be advantageous. Many research questions have yet to be answered both to direct these technological developments and to establish a wider acceptance of simulation in dental education.

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