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The use of simulators in the development of dental skills

O uso de simuladores no desenvolvimento de habilidades odontológicas

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ABSTRACT

Training dental students to be prepared to face real situations in the clinic with patients can be challenging and demand many laboratory hours practicing. Still, new technologies are currently available to contribute to the student's development of dental skills. This manuscript reviewed the global literature on using virtual, augmented, and haptic reality simulators in dental student training and discussed the advantages of simulators, such as their ability to provide a safe and controlled environment for students to practice, and their disadvantages, including the high

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initial cost and the potential for over-reliance on technology. The authors clarified the differences between the various types of simulators available and discussed their applicability in dental education. The studies reviewed indicate a global trend of incorporating simulators in dental education. This not only significantly enhances the pre-clinical training of dental students but also boosts their self-confidence as they transition into the clinical phase of their education. As dental simulators prove to be an effective strategy for learning, it is likely that they will become a standard part of the dental program curriculum.

Indexing terms: Clinical skills. Simulation. Virtual reality.

RESUMO

Treinar estudantes de Odontologia para estarem preparados para enfrentar situações reais na clínica com pacientes pode ser desafiador e exigir muitas horas de prática laboratorial. Ainda assim, novas tecnologias estão atualmente disponíveis para contribuir para o desenvolvimento de competências odontológicas do aluno. Este manuscrito revisou a literatura global sobre o uso de simuladores de realidade virtual, aumentada e háptica no treinamento de estudantes de Odontologia e discutiu as vantagens dos simuladores, tais como a sua capacidade de proporcionar um ambiente seguro e controlado para os alunos praticarem, e as suas desvantagens, incluindo o elevado custo inicial e o potencial para uma dependência excessiva da tecnologia. Os autores esclareceram as diferenças entre os tipos de simuladores disponíveis e discutiram sua aplicabilidade no ensino odontológico. Os estudos revisados indicam uma tendência mundial de incorporação de simuladores no ensino odontológico. Isto não só melhora significativamente a formação pré-clínica dos estudantes de Odontologia, mas também aumenta a sua autoconfiança à medida que fazem a transição para a fase clínica da sua educação. Como os simuladores odontológicos provam ser uma estratégia eficaz de aprendizagem, é provável que eles se tornem uma parte padrão do currículo do programa odontológico.

Termos de indexação: Competência clínica. Simulação. Realidade virtual.

INTRODUCTION

Dentistry is a career that requires the development of manual skills to ensure the successful performance of the techniques used in daily professional practice. Part of the training process for dentists involves repeating various exercises, many of which are conducted in pre-clinical laboratory settings, before safely treating patients [1].

Training undergraduate dental students, instilling in them interest, and preparing them for conscientious professional practice is a complex process. It demands knowledge and competence from educators, as well as creativity and an open mind to embrace the use of new technologies currently available to stimulate and facilitate learning. Students, in turn, are increasingly interested in using tools to make their training more dynamic and enjoyable [2].

The literature demonstrates the use of realistic simulators to complement traditional pre-clinical training methods. These assist in initiating student training in dental practices, ranging from simple procedures to more invasive and complex ones, including anesthesia techniques, incisions, and sutures [3,4]. In the near future, healthcare students will likely have simulator training in their curriculum [1].

There are different types of simulators for dental student training, and there are differences between the technologies and their optimal application in developing dental skills. This article aims to review the literature on dental simulators from different realities: augmented, virtual, and haptic. This differentiation

and detailing can contribute to the subsequent development of simulators that meet the training needs of dental students.

METHODS

For this literature review, a bibliographic search was conducted in databases available at the Virtual Health Library (VHL), Latin American and Caribbean Health Sciences Literature (LILACS), USA National Library of Medicine (MEDLINE/PubMed), and the Scientific Electronic Library Online (SciELO). Nineteen articles were selected for the study, considering scientific evidence from publications in the form of scientific articles from 2016 onwards, without any geographical limitations.

Types of simulators

Virtual Reality (VR) simulators provide three-dimensional virtual environments with real-time interaction, including varying degrees of immersion and realism, thus allowing for the accurate reproduction of essential tasks for healthcare training [5]. The simulations are high-fidelity, reusable, and configurable to provide various cases. They also can record precise data about individual performance, allowing students to practice independently and receive objective assessments of their work [6].

Augmented Reality (AR) aims to enhance an individual's visual experience of the real world by integrating digital elements. It is characterized as the combination of virtual and real scenes recorded in three dimensions with the possibility of real-time interaction. Therefore, an augmented reality environment allows users to see the real world with computer-generated virtual images. For use in Dentistry, the idea of integrating patient cases and augmented reality can contribute to quicker and easier visualization of abnormalities, locations, and anatomical points of interest. AR simulators can be used on mobile devices, such as phones and tablets, making access easier for undergraduates [7].

Haptic Technology (HT) in virtual environments is characterized by a bidirectional flow of information between the user and the computer-generated environment, through simulations of tactile and kinesthetic sensations by applying forces, vibration, or user movement. Dental simulators incorporating haptic technology fundamentally change how users interact with virtual objects, providing a realistic sense of touch, which is crucial for skill learning [8,9].

Background & Context

In 2016, Tori et al. [1] evaluated the creation of a simulation tool for dental anesthesia training with haptic reality. They used a tool classified as low-cost, which could be used remotely with a helmet or smartphone adapters, to simulate the inferior alveolar nerve block. The first stage of the project involved approaching the syringe and positioning it over the needle insertion point, which was carried out by dental professionals and professors, as well as novice dental students and students from other courses with no experience in the field. Eleven of the fourteen evaluated participants reached satisfactory levels in anesthesia application using the simulator [1].

Mirghani et al. [10] analyzed the sensitivity of a virtual and haptic simulator (Simodont, Nissin Dental Products Inc, Kyoto, Japan), in detecting variations in the skills training experience of dental students from all

years of undergraduate studies. The device demonstrated sensitivity in performance levels between novice and experienced students. However, it has not yet been possible to distinguish performance differences among experienced students at various levels. The authors concluded that research on this topic is highly promising in dental education practice and that the simulator has the potential to measure performance differences and contribute to student learning [10].

In 2017, Plessas [11] sought evidence supporting the use of virtual reality simulators to discuss the role of augmented evaluation and facilitation in dental student instruction. The results of his study showed that the use of this technology appears to improve student learning and skill acquisition and reduce the necessary faculty supervision time. However, the author understands that augmented virtual response cannot be used as the sole evaluation method.

Ta-Ko Huang et al. [12] investigated the development of virtual reality and augmented reality technologies since their implementation in Dentistry, as well as their progress in contributing to education. They demonstrated that VR and AR technologies positively affected student skills in training classes.

Vincent et al. [13] conducted a study to classify the contribution of virtual reality to conventional analog training environments and demonstrate the complementarity of conventional techniques and virtual reality in dental student learning. The students were divided into two groups: the first designated to perform cavity preparation on a haptic simulator, and the second to perform preparation on conventional plastic teeth. Both groups showed similar results in a final exercise performed on the conventional teeth used by group two. Virtual reality enabled an evaluation based on objective criteria and reduced the subjectivity observed in evaluations performed on plastic teeth. Considering the decrease in time spent on supervision and teaching, the authors inferred that haptic virtual reality should be considered as a teaching method by Dentistry professors [13].

In 2020, Osnes et al. [14] performed an exercise to validate the effectiveness of using virtual reality and haptic simulations in caries treatment. The exercise, which was to be completed in fifteen minutes, compared the performance of one hundred and twenty-nine participants, including one hundred and twelve first-year undergraduate dental students and seventeen practicing dentists, and consisted of removing caries along the amelodentinal junction and all enamel without dentin support, preserving as much healthy tissue as possible. The exercise, developed for the Simodont (Nissin Dental Products Inc, Kyoto, Japan) simulator, consisted of two training blocks, one containing green caries, while the other contained normal enamel caries. The results showed that clinically experienced dentists outperformed first-year students regarding precision and overall execution. This was due to professionals already having knowledge and previous experience in clinical cases [14].

Grande-Gomez [15] carried out a bibliographic review of scientific articles to examine the entire trajectory of simulator use in the development of clinical dental skills in university-level students worldwide. The historical context of simulators was divided into four periods: the first encompassing conventional manikins, emerging in 1984; the second referring to virtual reality and haptic simulators in the 1990s; the third mentioning simulators and robotics in 2007; and the fourth stage, referring to current simulators considered since 2015. Each of these stages was determined by the technological impact caused in each period, by the integration of these simulators into curricula and syllabi, and in the development of clinical skills in students. It was concluded that there is sufficient evidence that using simulators during pre-clinical university education develops skills in dental students [15].

Zafar et al. [2] performed a study in 2022 to determine the effectiveness of a 3D augmented reality mobile simulator for local anesthesia training through a game. The simulator had three learning modes:

study, three-dimensional simulation, and augmented reality. Most participants agreed to be excited and comfortable and found it easy to use [2].

Moussa et al. [16] made a systematic review considering 73 publications about the effectiveness of virtual reality and interactive simulators on dental education. Fifty-two of the selected studies showed significant improvement in educational outcomes and virtual technologies were positively perceived by all the participants. According to the authors, within the limitations of their review, virtual technology appears to improve education outcomes in dental students. Further studies with larger samples and longer-term clinical trials are needed to substantiate this potential positive impact of various virtual technologies on dental education [16].

A bibliometric analysis of the development of haptic and force feedback technology and its changing trends in dental education, from January 2001 to November 2022, was published by Hsu and Chang [17]. A significant increase in the number of haptic and force feedback technology publications were found in the last two years. Virtual reality is the main keyword that indicates more new integrative applications currently underway.

Puleio et al. [18] reviewed thirteen studies from January 2018 to June 2023, focusing on AR in dentistry, aiming to answer the question "Does AR increase the precision of dental interventions compared to non-AR techniques?". The results of this systematic review demonstrated that AR enhances the precision of various dental procedures, improving the precision of dental therapies [18].

Patil et al. [19] performed a systematic review to assess the efectiveness of haptic feedback device, Simodont (Nissin Dental Products Inc, Kyoto, Japan), in improving the skill development and learning outcomes of dental students during their preclinical training. The author's primary goal in that review was to evaluate Simodont as a complementary training modality for dentistry students and based on the evidence collected they considered that the simulator was effective in preclinical training of dental students, offering advantages such as unlimited reproducibility, objective evaluation of preparation by computer assessment [19].

DISCUSSION

In current dental education, undergraduate students often show insecurity and struggle when transitioning from pre-clinical to clinical practices, despite having received prior laboratory training. This difficulty arises when they are required to apply the techniques they have studied to patient care. Increasing the amount of pre-clinical training and providing more objective feedback on their work could enhance students' self-confidence and improve their initial performance in clinical settings. Many authors highlighted the significant enhancements that new technologies can offer, showcasing their positive impact on various fields [1,4,6,7,9-16] and supported the idea that the implementation of virtual reality (VR), augmented reality, and Haptic Reality (HR) devices is being recognized as an innovative teaching and training alternative for dental students.

There are various types of simulators designed for training students, with the most researched in the dental field being devices that utilize virtual and haptic reality [17-19]. As advantages of these devices, some authors [10,12] demonstrated that using haptic simulators reduces faculty supervision time and enhances student learning, especially when combined with traditional teaching methods using analog mannequins. We concur with the authors that haptic simulation can serve as a valuable tool for dental training. The potential of haptic simulators to inspire new possibilities in dental training technologies is truly exciting.

However, further research is necessary to validate and enhance this method. As Moussa's [16] reports, despite assisting in dental knowledge and student training, virtual reality has some negative aspects. For example, it can lead to a misunderstanding of theoretical knowledge, and the diverse characteristics of VR simulators highlight the absence of established educational standards. This lack of standards can negatively impact the outcomes of dental education.

According to some authors, more research is needed to investigate the long-term impact on skills acquired through training with dental haptic simulators [8,9]. However, contrary to this opinion, others state that there is sufficient evidence to conclude that using simulators during university pre-clinical training develops skills in dental students [15-19]. We believe that more longitudinal studies with larger samples must be evaluated to attest to the efficiency of using virtual, augmented, and haptic reality simulators in dental education.

For the implementation of new technologies in undergraduate dental education, considering the different types of simulators, we believe that haptic technology would be the most suitable, as it is the one that comes closest to clinical reality by developing tactile sensations from applications of force, vibrations, and movements made by the operator, which provides a very realistic touch for learning dental skills. However, developing augmented reality simulators may be more feasible initially due to their ease of execution. In any case, devices that contribute to the training of dental students and the development of specific skills for each area of the profession will complement the already established teaching methods.

CONCLUSION

The findings from the articles included in this literature review underscore the increasing value of augmented, virtual and haptic reality simulators in dental education. These technologies are not just tools, but invaluable assets for training undergraduate students in dental skills, especially during the initial stages before their hands-on experience with patients in dental clinics. As per the reviewed literature, haptic reality is the most commonly used method. While simulators are not yet ready to fully replace traditional analog simulators, the combined use of simulators and training on mannequins is proving to be the most effective strategy for learning.

Conflict of interest: The authors declare that there are no conflicts of interest.

Data availability: The research data are available in the body of the document.

Contributors

ALM Gazonato, conceptualization, research, writing – review & editing. BM Berto and IP Port resources, writing – review & editing. DG Diniz, writing – review & editing. MA Camargo supervision, visualization, writing – original draft, writing – review & editing.

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