

# Introducing Haptic Simulation as a Teaching Method in Odontology in Mexico. What the COVID-19 Pandemic Left Us

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## ABSTRACT

Haptic simulation is considered today as a complementary tool widely used in different medical areas, such as dentistry. The use of this technology in this area has been gaining more and more fields, due to the advantages it offers over traditional education methods, it allows students to practice in an unlimited way, in a very real scenario of what they will do in clinical practice, in addition to the simulation equipment allowing them to obtain feedback, discriminating in the user's learning level. This tool can be used in various procedures in different dental specialties, such as restorative dentistry, endodontics, oral surgery, and local anesthesia, among others. Although the introduction of this technology in dental education has taken many years, in our country, we have only had the first approaches, and we have observed encouraging results in the students, resulting in a positive experience for them, so we can assure that this type of new education model provides a better focus and quality to the preclinical training system in dentistry.

**Keywords:** Haptic Simulation; Simodont; Dental Education; COVID-19; Pre-Clinic

## Introduction

Over the past two decades, the technology based on haptic simulation has entered spectacularly into the scene and its use has grown exponentially. Borrowing from other high-risk areas that have been using this type of technology for quite some time, such as aviation and astronautics, in healthcare education, specifically in dental health, the haptic simulation has been refined as the most effective and efficient way to use it [1]. During the last few years, specifically

since 1988, the existence of systems based on virtual reality, such as haptic simulation, which consists of artificial simulation created by three-dimensional (3D) of a real-life environment or computerized situations used in dental education has influenced how a big number of sciences are learned [2,3]. It has allowed students to interact with the virtual reality environment by simulating vision in real-time, similar to what happens in the clinic area. The technology-based virtual reality is based on three main principles: immersion, interaction, and user intervention in the virtual reality environment. The principle of

immersion consists of the presence of a user in the virtual environment, while interaction indicates the user modification performance [2]. The dentistry equipment with some types of virtual reality are mainly camera-display systems or head-mounted systems [3].

In the conventional education for dental students, they acquire sufficient knowledge and skills in preclinical courses, however, this conventional type of education process has some challenges and limitations [4-6]. The process of dentistry education differs from education mode in other health fields due to the combination of theoretical, practical-laboratory topics and clinical exercises. Spatial imagination to acquire theoretical knowledge in dentistry is one of the essential requirements for students to learn to dimension what the environment they will face later in the clinical setting will look like. However, this requirement might not be fulfilled in traditional learning environments. Therefore, using new technologies such as virtual reality, and haptic simulation, for example, has demonstrated to be an effective solution to improving the quality of dental education. In this sense, the haptic simulation is used as a complementary tool very useful in teaching practical skills to dental students before facing real patients [4-6].

### Haptic Simulation in Medical Education

Virtual reality-based training has been used in many fields of medicine for learning a wide range of skills that include medical history taking, clinical assessment, procedures of surgical anatomy, diagnostic procedures, operative, and/or surgical interventions, among others [7]. In this regard, students in medicine, dentistry, nursing, clinical chemistry, and physiotherapy, among other disciplines, have made use of this technology in their learning methods. Over the last decade, the use of haptic simulation, which is virtual reality-based training, has been growing in healthcare education and appears to have a positive impact on supporting the development of clinical competence of students at different levels of knowledge [7,8]. Simulation-based clinical training and assessment have become popular in some specialties in a variety of countries and many universities have adopted this technology, while certification organisms are proposing new ways to incorporate simulation into requirements for initial certification, continuing education, and continuing certification, for quality and improvement of teaching methodologies [9]. Therefore, to provide quality medical care, it is important to promote a good relationship between healthcare providers and the environment, thus simulation is a helpful and indispensable tool for this purpose. Another application of simulation in health education is that it allows for a more in-depth study of human features in patient care since it is a very suitable tool to better understand the interaction between human beings and the environment [9,10].

There have recently been a series of events that have led to greater growth in the use of haptic simulation in different clinical processes in health education. These factors include an increasing focus on

ensuring patient well-being and care, modifying traditional teaching and learning models, while providing new standardized educational opportunities based on the need to practice and refine skills in a controlled and safe environment. For instance, in the field of surgery, it has been developed that the use of simulation is crucial for the acquiring and development of hand skills. It was observed in a group of sixteen surgical residents an improvement in speed, economy of movements, and decreased committing errors during a cholecystectomy when trained in a virtual reality simulator [11]. Furthermore, the great benefits provided by simulation in the clinical environment have been reported with increasing frequency, which adds greater validity to its use in health education [12-14]. Ensuring the effectiveness of haptic simulation as an educational modality depends on how well this technology is used. Simulation should be used as a complementary form to the traditional teaching method, to promote good patient care experiences, and its integration into the curricula of universities in the health area should be well-planned and results-oriented [12-14]. In complex medical areas such as neurosurgery, it has been shown that the use of technologies like 3D printing and mixed reality, improves the development of surgical skills, decreases making mistakes and the facility to observe brain structures hard to reach in an *in vivo* model [15].

Haptic simulation-based education as a solution to the new model of healthcare education must incorporate the technology of simulation as a complement to clinical training, in a context of ample opportunities and achieve better competencies in terms of skills acquired by students [12]. In recent years, sufficient scientific evidence has been generated to support the use of virtual reality technologies, such as haptic simulation in health education, demonstrating that simulation practice is similar to traditional clinical education. Haptic simulation might also substitute clinical experience to ensure the needed exposure to a range of clinical cases. This is a necessity, due to increasing limitations for clinical training opportunities in different areas or lack of patients in any situation. Among the different simulator models that exist, some provide feedback in the software and some even give a rating to evaluate the user's performance during the procedure used. This "real-time" feedback allows instructors to evaluate student procedures in a fair and standardized manner [7,16,17]. Simulation-based education is also part of the solution in the context of reducing medical error and promoting patient safety since students can practice a procedure countless time in the simulators, until they master it, before executing it on the patients. Therefore, simulations are a crucial component in improving patient outcomes [18-21].

### Haptic Simulation in Dental Education

Technology based on haptic simulation has been introduced in recent years as a complementary approach to traditional simulations in the training of dental education. This new digital technology is becoming more and more popular for learning dental procedures and favors the acquiring of technical skills in dentistry students, among

many other advantages that it presents. Several studies show that the use of haptic simulators in dental education in preclinical training significantly increases motor skills acquisition, in different dental specialties, promoting a positive impact through a faster acquisition of skills [22,23]. The trend of using virtual reality through haptic simulation to support the learning of students in the dental area has grown in recent years, the universities have implemented the use of this technology, for example, one of the basic and more used procedures by haptic simulators is performed to caries removal and cavity preparation, however, the haptic simulation is applied at different areas, as restorative dentistry, prosthodontics, local anesthesia, oral surgery, periodontology, endodontics, and more [2,24].

Several publications point out the increase in the use of different artificial intelligence technologies in the dental area, classifying by areas, leading dental radiology (26.36%), orthodontics (18.31%), restorative dentistry (12.09%), and maxillo-facial surgery (11.87%) [25,26]. Preclinical dental training enables students to acquire various motor skills before they have contact with patients and in this regard, the simulators have been used to recreate a panorama with a wide variety of dental procedures and thus prepare students for clinical practice [25,26]. A very highlighted example is restorative dentistry, specifically operative dentistry, where the pre-clinical training aims at developing manual dexterity in students, which is fundamental for developing skills and competence in operative techniques across the board and that will be useful in other more complex procedures. An explorative study was performed at the College of Dental Medicine in the Qatar University, where 23 undergraduate dental students were evaluated under two different perspectives: by using the phantom head and acrylic typodont teeth, while the second group was trained by using the virtual reality haptic simulator (VRHS).

According to the perception of the students concerning cavity preparation, self-confidence while doing the procedures, grip simulation, among others, the use of VRHS is highly desirable during their pre-clinical stage [7,27]. Manual dexterity by part of students needs the development and consolidation of psychomotor skills and requires simultaneous hand-eye coordination. This is where practice is very important and one of the advantages of using haptic simulators is that they allow their use an unlimited number of times, with their respective feedback, until the student develops the necessary skills [28]. This is a relatively new educational approach that has several advantages above the conventional approach. The simulators that have incorporated this novel digital technology can graphically and haptically simulate real-world clinical situations to improve fine motor skill acquisition in students. Unlike conventional simulation, haptic simulators allow a self-assessment approach to enhance students' autonomy, through programs of positive feedback. The use of haptic simulators in the early phases of preclinical dental training can improve student performance and accuracy in several dental procedures, and also provide unlimited training hours [28,29].

At the Egas Moniz School of Health and Science, 20 preclinical dental students enrolled a study aiming to determine whether the use of haptic simulation with the DENTIFY™ equipment was in accordance to the results obtained with the traditional phantom model, during operative dentistry training. Participants performed different tasks all related to cavities creation in different teeth, obtaining a significant improvement when they had previous training by using the haptic simulation [30]. In this regard, a recent generation of dental devices based in virtual reality through haptic simulation has been introduced in the market, there are robotic devices that simulate the clinical environment in a very accurate way, there are devices equipment with advanced features, and others with minimal software development [19]. Various forms of haptic simulators exist, including cutaneous feedback, which relates to pressure, shear, and vibrations applied to the skin, as well as kinesthetic feedback, which encompasses the forces and motion perceived by the muscles, tendons, and joints [7,31].

In addition, it has been reported that dental students perceive the haptic simulation as a useful tool for enhancing their dexterity manual. Since the feedback is provided by simulators, this allows for to maximization of the learning experience, being an essential point to effective learning in simulation-based education. In addition, the compelling pedagogical results on dental haptic simulators evaluated the pedagogical effectiveness of virtual/augmented reality and haptic technologies in dental education and concluded that virtual technology appears to improve education outcomes [32]. In this regard, eleven full-time academic staff from the School of Dentistry and Oral Health at the Griffith University in Australia, underwent a perception study by using the SIMODONT equipment. A positive generalized opinion was observed when the professors used the SIMODONT exercises, considering that certainly, the use of haptic simulation could not replace traditional teaching methods, the use of it could be of great support for the pre-clinical students [33].

### Haptic Simulation in Mexico

Currently, most dental schools, including ours, use acrylic tooth models to train students in caries removal and cavity preparation for adequate pre-clinical training, before providing oral care to real patients. Having sufficient skill and ability to perform these types of procedures is considered an essential competence for university dental students. It provides them with the basis to apply them to other common dental procedures, such as endodontic accesses, veneers, crown preparations dental preparations for removable prostheses, and more. Since removing caries and creating a cavity is perhaps one of the most common and simplest dental procedures, the objective of performing these procedures is to prepare the student for more complex challenges in the future [7,34]. Osnes, et al. in 2020 developed a short training exercise of caries removal with 1st grade dental students at the School of Dentistry in the University of Leeds. After the use of the simulator SIMODONT, the students showed a better com-

prehension of the anatomy and textures of the damaged teeth, as well as increased precision and in general an improved performance [35]. Haptic simulation has been used in dental education, through phantom heads and mannequins to simulate the work of different dental procedures with real instruments and materials, providing students with a plain realistic, and effective training experience [2,7,36]. The ability to develop procedures in an unlimited way in a safe, reliable, and controlled environment without the risk of damaging the integrity of a living patient or committing iatrogenies, due to the lack of practical knowledge, is a great advantage of pre-clinical training based on haptic simulators [2,34]. The use of haptic simulation in dental education has been shown to improve students' motor skills and increase their confidence when performing procedures in a clinical setting. It is for this reason that we have been concerned about improving the teaching of our students therefore acquiring haptic simulation equipment in this faculty, inaugurating the haptic simulation laboratory [37].

Therefore, today, a new approach that is complementary to the traditional teaching method has been introduced into the field of dental education. This new way of learning aspects of pre-clinical training is based on the use of technology haptic simulation, which provides feedback on the procedures performed. Thanks to the use of virtual or augmented reality environments that model clinical situations, haptic simulators provide realistic, visual, auditory, and tactile sensations through their interface. The objective of implementing this new technology in dental education is to assist in the training of students in pre-clinical training [7,17,38]. We know that the initiative by our institution, which is one of the first in our country to support virtual simulation technology, ensures a planned integration into the curriculum to optimize the benefits that this entails for the improvement of education. In our country, pre-clinical students use mannequin-based phantom heads and typodont teeth in a conventional simulation environment. Preclinical phantom head or mannequin training is a widely used pedagogical strategy in dental education that uses a simulated human head or mannequin to provide students with a safe and reliable environment to begin developing their skills. These types of training models are designed to imitate the physical features and anatomy of a human head, including teeth, gums, and jaw, allowing students to practice common dental procedures such as tooth extraction, and the preparation of crowns, in addition, these devices providing laterally movements, opening and protrusion [2,28].

However, we have joined the current teaching models, equipping a haptic simulation laboratory, with 52 phantoms of last generation (Nissin Dental Products Europe BV, Nieuw-Vennep, Netherlands), 1 Simodont (Nissin Dental Products Europe BV) simulator and 1 scanner for cavities preparation and qualification (fair grader 2000, Nissin Dental Products Inc, Kyoto, Japan). Simodont is a dental training simulator that uses haptic simulation technology where dental procedures can be performed in a virtual, tactile, and realistic way, also providing feedback on the procedures performed [2,39]. The Simodont

system is widely used in dental schools around the world, this system can be customized to simulate various dental procedures, providing students with a comprehensive and immersive educational experience [39]. The system uses advanced sensors and algorithms to track and analyze a variety of parameters such as instrument pressure and angle, movement speed and trajectory, and procedure duration. In addition, the system that Simodont owns can supervise a student's pre-clinical work, in such a way that it can identify whether the student is working on the correct tooth and if he is damaging the soft tissues or the gums. This data is used to provide personalized feedback to the student, identifying areas of too much or too little pressure, or if they are going off track. This feedback is obtained according to the needs and skill level of each student, since it allows us to discriminate the level of knowledge of the students, providing an effective learning experience [27,39-42].

One of the important features of the Simodont is the generation of three-dimensional images through stereo viewers, which impacts the performance and perception of users. One of the many advantages provided by this simulator is also that it has been seen to reduce anxiety levels in dental students, since they practice in a very real, safe, and reliable environment, being able to repeat a dental procedure unlimitedly until you master it [37]. Haptic simulation as a new teaching method is a very useful complementary tool to the phantom head in dental education. Using these methods in combination, as pre-clinical training devices, is superior to either of them alone. However, it is necessary to continue with research on the use and sequence of the two systems, as well as the implementation, above all, of haptic simulation in the curriculum, not only at the undergraduate level but also in postgraduate courses in dentistry. These actions are essential to promote quality and effective teaching within dental education institutions, which will be reflected in better oral care for the population [43]. Although this technology has been used for 2 decades in other countries, it is a great achievement for Mexico, especially for our institution, to be one of the pioneers in Latin America in the use and acquisition of this equipment, which will significantly improve dental education in our country.

### **The New Normality After COVID-19 Pandemic**

Since the end of December 2019, the entire world faced a pandemic without precedents seen before. No country, even a world power, was prepared for all the havoc that the COVID-19 pandemic brought with it [44]. Each country decided to face the pandemic, according to its possibilities and considering the international measures established by the World Health Organization (WHO). Thus, each government, based on its health system, adopted the necessary measures. For example, in our country, the quarantine was established, the "stay-at-home" program was disseminated, measures were established to avoid contact between people, most establishments closed temporarily and we had to work from home. New temporary health systems were created, such as sentinel surveillance centers and gen-

eral hospitals became COVID-19 hospitals, where exclusively patients infected with SARS-CoV-2 [45]. However, the infections spread despite the established measures, and the quarantine became longer than expected, so there was a need to return to daily life, adopting new normality, since the confinement was not sustainable over the months and years.

Regarding education, at the beginning, the various educational levels scheduled their classes virtually. However, later, students began to progressively return to the classrooms, a few days a week and rotating students, so as not to saturate the space. This is how the use of technology began to increase, due to the need to resume classes, even if it was at a distance [44]. In principle, this does not represent any problem, since theoretical classes do not necessarily require the presence of the teacher, we have learned, thanks to the pandemic, to study through the screen. The real challenge was presented at the superior education level, specifically in universities in the health area, since this is where practice is fundamental in the training of students [45,46]. For example, in our area, dental, as part of the curriculum at this university, students from the fifth semester onwards begin to have contact with patients, this is due to the great demand for providing oral health services to the population and the economic ease, to offer services at prices well below the average, since it is a federal public university. However, this represented a problem, since there were no patients available, dental students could not carry out their practices efficiently and/or sufficiently.

A solution to this problem has been the introduction of haptic simulation technology within the Stomatologist career curriculum since the use of simulators allows students to practice an unlimited number of times and in a scenario very real as if they were in the clinic. This had an important impact on the teaching method since the use of these technologies has changed the traditional way of learning. That is, it has not replaced what already exists, but rather it has served as support and reinforced the education system in the dental area. Above all, it allowed us to continue learning in times of pandemic, to ensure that students continued with their academic preparation and were not affected by the lack of performing procedures on patients during the pandemic. To support this information, several studies reveal results of an unprecedented boost of publications in recognized publication media, such as Scopus, Web of Science, and PubMed during the years 2019–2021, which might imply that the COVID-19 pandemic served as an accelerator in the implementation of AI-powered technologies in dentistry [2,47]. The pandemic situation may have forced an accelerated utilization of smart technologies that are often combined with telehealth solutions. From what we can assume, this has been one of the few good things that the COVID-19 pandemic left us.

## Discussion

Haptic simulation-based education and training has proven effective in multiple areas, specifically, in health areas, where it has been

shown to improve the acquisition of medical knowledge, allowing the development of basic and specific skills, also, reducing stress of students during procedures in the clinic, promoting greater confidence with patient management. Haptic simulation is also a valuable evaluation tool since it is used as a methodology for evaluating psychomotor skills by users. It has also been used successfully to assess competency development. Thanks to this, haptic simulation in medical areas, it has become a standard evaluation method very used nowadays [39]. Several studies about the use of haptic simulation in medical areas, such as odontology, have found a real benefit in terms of time, and individualized training by part users [24]. In these ways, students can be trained more quickly in a particular procedure with systematic feedback, and their progress curves are accelerated. For example, Al-Saud et al. concluded that virtual reality combined with instructor feedback helps optimize the acquisition and retention of certain basics in conservative dentistry skills [39]. The use of haptic simulators in odontology, coupled with virtual reality, for which realism is constantly improving, enables students to repeat procedures an unlimited number of times until the procedure is mastered by students. Furthermore, another unknown but crucial advantage of haptic simulation, is that it represents an ecological advance since it limits the great amount of waste produced by the use of plastic materials in traditional simulation methods.

Since its inception in the odontology area, the haptic simulation in dental education has shown better efficacy in teaching than traditional techniques through more effective learning and systematic feedback, offered by actual simulators. These results are particularly supported in varied areas of odontology, such as implantology, oral surgery, prosthetics, pediatrics, radiology, restorative dentistry, and endodontics, where the haptic simulation has gained relevance [39]. Other studies concluded that the big advantage of the use of haptic simulators in odontological procedures lies in the importance of distinguishing users with different manual skill levels since the simulators discriminate the students according to their initial level of manual dexterity [38]. This point is relevant because this allows dental students the use simulators at any level. Therefore, considering all the advantages, the learning methods through haptic simulators are educational options that should be considered by universities of odontology.

## Conclusion

All revised literature about the use of technologies of virtual reality as haptic simulation, highlights the importance of the complementarity of the traditional and virtual teaching methods in the training of students in the dental area and shows that virtual reality prepared the students for an adequate environment, acquiring more ability, skills and forging more confidence in the managing of real patients. As part of teaching dental education in our university and despite its recent introduction, the haptic simulation has served to improve the transition to analog training, allowing the use of these technolo-

gies and having very good acceptance by the student community. To evaluate the basic dexterity in students of odontology should be an essential part of initial training and continuing education and thanks to these new devices these skills can be evaluated. The development and implementation of new objective evaluation criteria could be a solution to improve student self-assessment and this way being able to provide quality dental services to the population, since the use of these technologies allows students to practice and being evaluated, to minimize errors or iatrogenic and provide necessary skills for dental medical care.

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## Conflict of Interests

The authors do not present a conflict of interest.

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