RIDES: Realistic and Immersive Dental Education Simulation Using Virtual Reality and Haptic Device Implementation

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Abstract— **Virtual reality (VR) is an emerging technology for simulation and training experiences in a variety of fields. It is becoming widely available and increasingly accessible in cost. The field of dentistry can greatly benefit from the use of this technology as it presents breakthroughs that augment the education process. In this paper, the authors developed RIDES: Realistic and Immersive Dental Education Simulation. In this project, the authors implemented VR technology and a haptic device to allow dental students to train their psychomotor skill virtually, all while maintaining a realistic experience and an easy to navigate interface. This simulation can be experienced from anywhere, given a sufficiently powerful computer, and does not require the professor to be physically present. This distinction was vital to the continued education of students after the Covid-19 global pandemic. The social distancing restrictions that were implemented for public safety severely limited in-person education, which prompted the exploration of digital methods. It allows for a digital approximation of a task that gives the user freedom to explore the subject without fear of damaging expensive equipment before given the proper training to handle it. By utilizing the immersive virtual reality capabilities of the VR headset and the realistic tactile feedback of the haptic pen, the authors developed a unique and realistic simulation for dental education.**

Keywords-virtual reality; haptic device; dental simulation.

I. INTRODUCTION

At the end of 2019, the world was alerted to a high number of pneumonia-like disease cases in Wuhan, China. This disease was identified to be caused by a novel coronavirus, named by the International Committee for Taxonomy of Viruses as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The World Health Organization (WHO) later announced this disease as the Coronavirus Disease 2019 (COVID-19). COVID-19 was known to be an airborne transmission disease because the virus efficiently spread from person to person through respiratory droplets by sneezing, coughing and direct contact. This infection affected 222 countries and territories around the world, prompting WHO to declare COVID-19 as a pandemic in March 2020. As the situation worsened, many countries implemented restrictive mass quarantines and lockdowns to decelerate and break the chain of infection.

The COVID-19 pandemic led to a sudden shutdown of institutions in 2020, including the United States of America. The US government implemented a lock down order to encourage the public to stay at home and practice social distancing. This condition forced all educational institutions to be closed, halting all face to face education. For dental students, all clinical and lab practice sessions were halted. As a consequence of this pandemic, all universities in the US were strongly affected and were forced to face the new challenge of implementing "distance/online learning".

In restorative dentistry, cavity preparation concepts have evolved towards a tissue-sparing approach, requiring a high level of skill and precision when preparing cavities. Traditionally, preclinical dental instruction was accomplished in a bench-type laboratory environment where students learned psychomotor skills using hand-held dentiform or mannequin heads mounted on metal rods. Recently, computer-assisted training systems such as *Simodont* are developed and used for the practical training of dental students. However, this technology showed some limitations. The cost, both hardware and learning modules, is expensive. The product's size and dimension also pretty big therefore it is site-dependent. Student needs to come to the college to operate the machine.

Virtual simulation such as VR could potentially provide efficient educational pathway to achieving a high level of practice. The use of haptic simulators coupled with virtual reality is expected to address the limitations of native VR controller regarding tactile feedback. The objective of RIDES project is to develop a VR simulator coupled with haptic device as an educational tool for tooth cavities preparation. While an integration of VR and haptic has been explored in several directions previously, the application of these technologies for dental education specifically cavities preparation teaching session is a novel direction.

In section 2, it covers several related previous works that we observed as references. Section 3 discusses about our project, RIDES. In this section, authors describes technical aspects including VR headset and haptic device that we used. Authors also explain about the VR experience related with this project. Finally, in section 4 authors will close it with summary and potential future development.

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II. PREVIOUS WORKS

Related with VR applications for implant surgery, Matsuo et al developed a virtual reality head-mounted display for endoscopically-assisted implant surgery [1]. Several VR haptic projects were explored. The group of researchers published a paper regarding haptic interaction for needle insertion training in medical applications. In this project, the authors developed a virtual needle insertion training simulation based on haptic interaction [2].

Our project is inspired by the work done by a previous research group [4]. In that project, authors implemented VR for implant surgery simulation as shown in Figure 1.

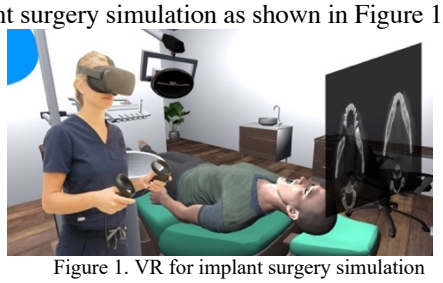

Figure 1. VR for implant surgery simulation

Based on the conducted study, it was concluded that the application of VR technology in dental education was promising and offered positive learning enhancement. However, several study participants suggested the lack of haptic sensation including feeling the tissue density when using rotary and surgical instruments.

III. RIDES PROJECT

To tackle the tactile/haptic limitations from previous study, our current research team explored the implementation of haptic device into VR learning module, specifically cavities preparation training. In the beginning, the authors tried to integrate haptic gloves as shown in Figure 2. Since the primary goal in the cavity preparation simulation is to drill into a tooth, the authors observed that the haptic gloves were not an appropriate input device for an accurate simulation because it has no resistance feel. The glove also proved to be unintuitive for new users, as well as generally unrealistic for the purposes of the simulation.

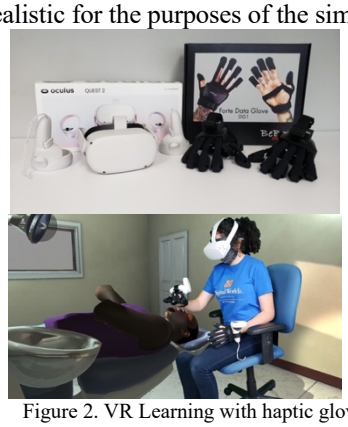

Figure 2. VR Learning with haptic glove

Due to this issue, the authors decided to switch over to a 3D Systems Touch Haptic Pen (see Figure 3). It is a desktop stylus that hangs on rotating motors that can lock on any axis to simulate the stylus coming into contact with an object in the virtual world. The haptic pen provides a more realistic approximation of using a handheld drill, while making it easier for the user to interact with the dentistry experience. The combination of rumble motors and locking arms could simulate tooth drilling, largely because the user is holding an object in the physical world that they are also using in the virtual realm to manipulate the tooth.

Figure 3. 3D Systems touch haptic pen

The purpose of this project was to simulate dental training, specifically tooth cavities preparation, with virtual reality and haptic feedback as shown in Figure 4. This would enable dental schools to provide their students with the real life experience that they require without spending the usual amount of time and resources needed to teach them in person. When students are given training in a virtual environment we expect it can help them to become more confident when working and practicing in the real world, potentially reducing or eliminating mistakes. This also gives students more time and accessibility to practice skills they've learned in classes. Techniques that need many hours of practice to master are more easily rehearsed with a virtual reality program that can be used anytime outside of the classroom.

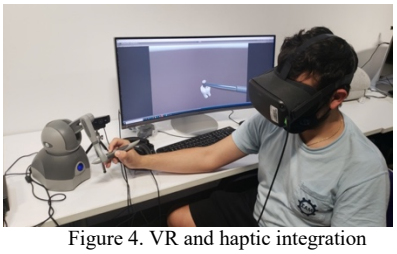

Figure 4. VR and haptic integration

A. *Cavities Preparation VR Training Session*

One of the essential activities for cavity preparation is drilling. The haptics pen allows us to replicate the drilling experience inside computer-generated environment. Furthermore, the haptic pen could also provide a resistance sensation that is important to achieve the learning goal.

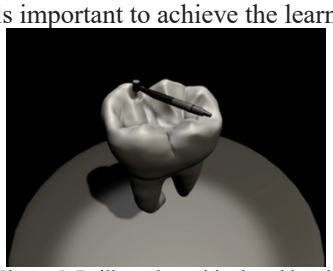

Figure 5. Drill session with virtual handpiece

As shown in Figure 5, the virtual hand piece controlled by the haptic pen is able to deform the mesh of the tooth and mimic the conventional cavities preparation training session. The authors also arranged the drill to vibrate at different frequencies to emulate the different layers of the tooth by tracking the depth of the pen in the tooth's mesh.

To complement the training session, the authors offered a "pop-through" feature that enables users to pop through the drilled tooth and analyze their result as shown in Figure 6. When user in this state, they also have an option to change the transparency of the dentin layer. This will allow them to compare their drill result with the overall tooth anatomy structure, including nerves (see Figure 7)

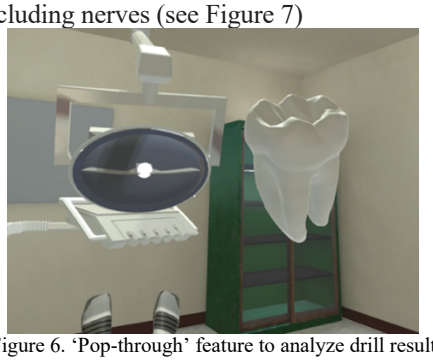

Figure 6. 'Pop-through' feature to analyze drill result

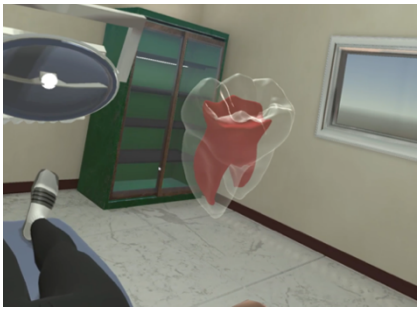

Figure 7. Transparency adjustment feature

IV. CONCLUSION

The COVID 19 pandemic surged the urgency to utilize distance learning for all education levels including higher education. However, it is quite challenging to deliver psychomotor skill-related training using conventional online learning modalities. Immersive learning using VR technology is one of the emerging solutions and in this project, the authors also integrated a haptic device to provide a more realistic immersive learning experience in the dentistry direction.

For this project, the authors developed a haptic VR learning simulation for cavities preparation entitled RIDES: Realistic and Immersive Dental Education Simulation. When this project started the authors explored BeBop haptic gloves, however this device lacked the resistance feel that is essential for the cavity preparation learning process. Therefore, authors switched to the haptic pen which offered a more realistic learning experience and the possibility to mimic a conventional training session. The implementation of the haptic pen is expected to answer limitations from previous study, namely the lack of a resistance sensation.

In the future, the authors plan to extend this project so it could accommodate multiple VR users interacting with each other at the same time. Therefore, the instructor or professor could meet with their student and run the training session inside the VR environment. This multiplayer feature will also open an opportunity to run a test session where the professor or instructor could examine their student's progress from distance. The authors also plan to conduct several user studies including measuring the effectiveness of this project, the user perception, and others.

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