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Article

Development and Student Perception of Virtual Reality for Implant Surgery

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Abstract: (1) Introduction: New and innovative approaches to dental education have continued to improve with time. The coronavirus disease 2019 (COVID-19) pandemic forced dental education to change as social distancing implementations were enforced. Virtual reality was used as a resource before the COVID-19 pandemic, and it has become more essential due to social restrictions. Virtual reality can allow students to be fully immersed in a clinical environment without leaving their homes. (2) Methods: The development of virtual reality (VR) for implant surgery was described. Selected students filled out a survey before and after using the program. Then, a focus group discussion for the students was held to analyze the program further. (3) Results: Seven dental students enrolled in the Advanced Predoctoral Implant Program (APIP) participated in the study. Qualitative analysis of this study suggests that virtual reality can be used as a supplemental resource to enhance student learning of specific topics. Additionally, the students had positive outlooks for using virtual reality as a resource in dental education and were hopeful to use it in the future for particular topics and subjects. (4) Discussion: The advantages and disadvantages of VR application in education were described. This application allows the students to be immersed fully with virtual dental operatory. The application provides the student with an enhanced learning experience in implant dentistry. Students displayed supportive attitudes towards the applicability of VR in dental education but considered this application as an adjunctive tool for learning. (5) Conclusion: The application of this technology in dental education is promising. The use of virtual reality in teaching and learning implant dentistry offers positive enhancement, especially during these challenging times.

Keywords: virtual reality; implant surgery; development; student perception

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1. Introduction

The incorporation of technology in the dental field is continually changing as it pertains to daily dental practices. Computer -Aided Design and Manufacturing (CAD/CAM) [1–4] and computed tomography [5] technology have been commonly used for diagnosis and restorative phases. The advancements of technology have revolutionized the way we practice dentistry. However, the use of technology as a teaching tool in dental education is often very limited. Currently, preclinical instruction on typodont teeth is still the most common practice. In addition, three-dimensional teaching tools have been created to use as an aid for certain topics such as dental anatomy [6,7].

More recently, extended reality (XR) has been used as an immersive teaching tool. Extended reality represents the entire spectrum of possible technical representation modes, such as augmented reality (AR), mixed reality (MR), and virtual reality (VR). AR is a technology that superimposes a computer-generated virtual scenario atop an existing reality to create a sensory perception through the ability to interact with it [8]. MR integrates the computer-generated scenarios atop existing reality instead of just superimposing

the objects/scenarios. VR is an artificial computer-generated simulation of a real-life environment [8]. The program used in this study is classified as a VR program.

XR has been widely used as a teaching tool in medical education. For dental education, VR has been used mostly to train oral surgery residents for orthognathic surgery [9], teach dental anatomy [7], treat dental phobia [10] and reduce anxiety [11]. On the other hand, AR technology has been used mostly to communicate the esthetic result [12] and teach dental anatomy [13]. Unfortunately, these technologies have not been incorporated as broadly. This may be due in part to dental education having challenges offsetting the difficulty in designing a cost-effective program while also designing software that can be commonly used. For example, Simodont is an effective teaching aid [14,15] but comes at a high cost. It can only be used in a school setting as it is not portable. The gap to be bridged is to have a VR teaching aid that can be transportable, at a lower cost, for students to use the program remotely.

COVID-19 has placed increasing pressure on these teaching tools as remote and distanced learning is needed amid the pandemic. Dental schools are faced with growing challenges when it comes to assuring proper student training which also ensures student and faculty safety. Specifically, in dentistry, the hands-on nature requires many procedures to be demonstrated by faculty in close quarters with students. VR programs through the Oculus can offer a low-cost approach for student and faculty engagement during training while ensuring safety. The objectives of this study were to describe the development of virtual reality for implant surgery, and to investigate student perception of the use of VR in teaching dental students dental implant placement.

2. Material and Methods

2.1. Development of Virtual Reality for Implant Surgery

VR is defined as a computer-generated digital environment that can be experienced and interacted with as if that environment was real [16]. Furthermore, Milgram and Kishino developed a virtuality continuum that spans from the real environment (on the left) to virtual environments (on the right) with augmented and virtual reality in between (Figure 1) [17].

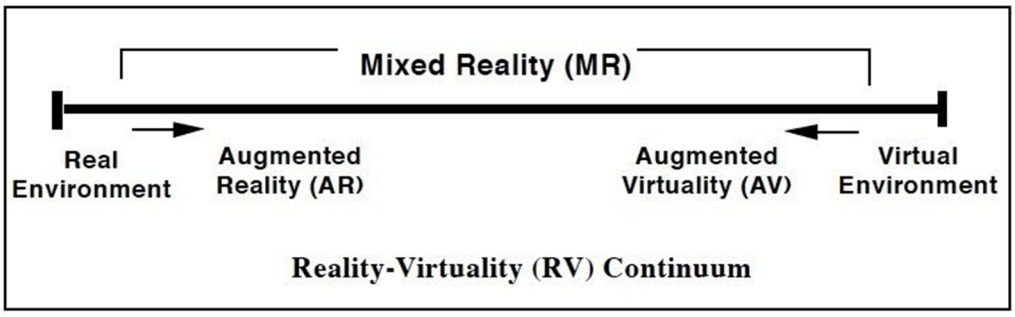

Figure 1. Milgram and Kishino's virtual continuum.

VR provides an immersive experience and can be described as psychologically being in a place different from where one is physically located. That new place could be anything, from a real-world replica to an imaginary world that does not exist, has not existed, or never could exist. [16] VR is also presence where it is simply stated as a sense of "being there" inside a space, even when physically located in a different location. While technology's characteristics highly influence immersion, presence is an internal psychological state of the user. The authors expected the combination of immersion and presence would be sufficient to train the user's spatial ability in dental implant application.

In this project, a head-mounted display (HMD)-based VR experience was used. HMD is one of the stereoscopic techniques, and it is a device worn on the head or as part of a helmet. It has a small optic display in front of each eye [18]. The more advanced HMD

setup has a six-axis position degree-of-freedom (DoF) to allow the user to "look around" the virtual world with their head orientation and move around to the respective direction. There are two types of HMD based on the see-through approaches: optical and see-through video display [19]. In this project, the latest untethered VR HMD or headset manufactured by Facebook, Oculus Quest, was employed.

Oculus Quest was used for a couple of reasons. First, inside-out tracking: this feature removes all additional external sensors or trackers and reduces all complicated calibrations to run the VR application. Second, both headset and controller are equipped with 6 DoF sensors, and it will fit with the requirement for this project. We developed the VR project on the Unity engine accompanied by the Oculus Software Development Kit (SDK), version; 25.0 (Menlo Park, CA, USA) released by Oculus. This SDK is specifically prepared for the Unity engine, and it works across all Oculus product lines such as Rift S, Go, and Quest. Quest is an untethered VR headset that comes with 2 controllers. Both headset and controllers are six DoF, and track the user's head and body movement in a real space then translate it into a VR world with realistic precision. Quest controllers are equipped with buttons such as thumb sticks, menu buttons, oculus buttons, grip, and triggers (Figure 2A). Additionally, Oculus Quest is also equipped with front-facing cameras, and these sensors can track the user's hand to enable hand-controlled interaction (Figure 2B). With this feature, the users could use their hands to interact and engage with the VR content. However, in this project, we decided to build a set of interactions based on the Quest's native controller.

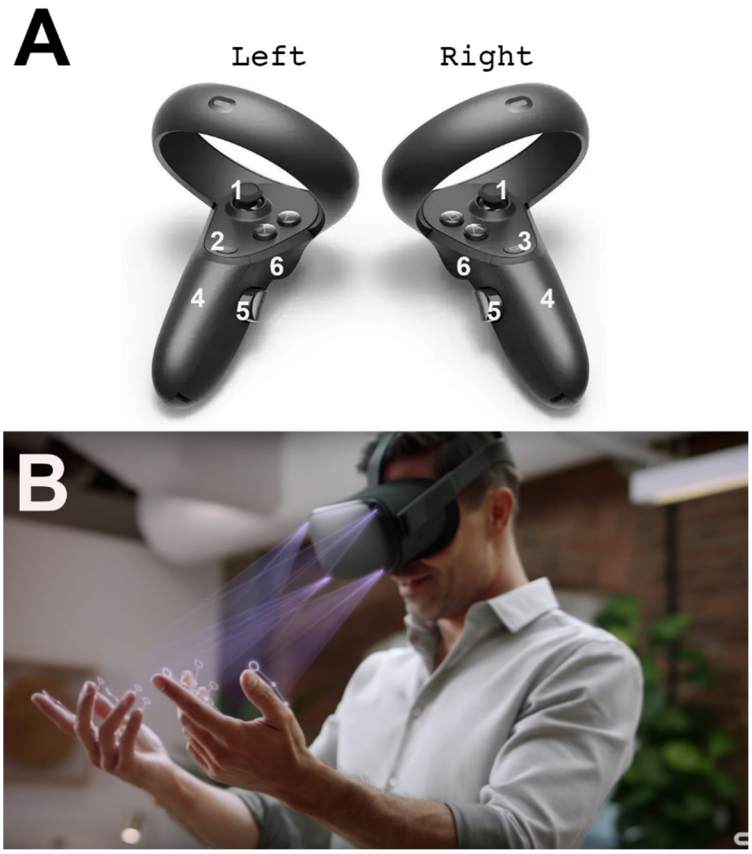

Figure 2. (**A**) Oculus Quest controller (1: Thumbsticks, 2: Menu Button, 3: Oculus Button, 4: Battery Covers, 5: Grip Buttons, 6: Triggers), (**B**). Front Facing Cameras

This project mimics the real-life scenario in a dental operatory and brings it into the virtual setup (Figure 3). Several essential supporting features were included to replicate the dental implant surgical procedures. These included a patient, surgical drill, implant kit, surgical knife, cheek retractor, and a handpiece (Figure 4).

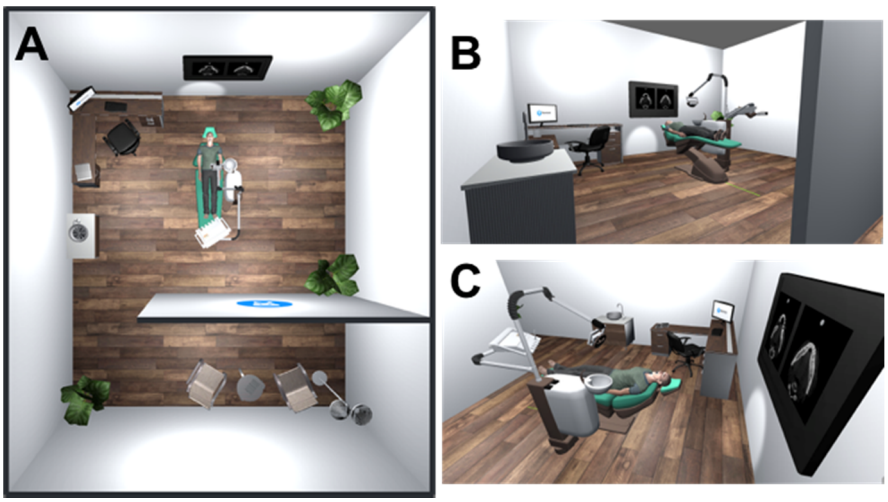

Figure 3. Virtual dental operatory room layout (**A**) top view, (**B**,**C**) view of operatory room with patient's CT scan.

Figure 4. (**A**) Patient with cheek retractor, (**B**) drill and implant kit, (**C**) surgical knife, (**D**) hand piece.

Once the users immerse into the virtual surgical room, they will be able to walk around the scene and explore it. Since Oculus Quest is equipped with the room-scale tracking feature, the users can calibrate their room and align it with the VR environment; therefore, users can explore the virtual scene by moving around in their real space. In addition, the left thumb stick button can be used to advance their virtual avatar inside the VR room. The operatory room is the main room where the user can interact with the patient and practice the implant surgical procedure. This project is designed as a patient-specific simulation tool where the teeth and mandibular arch were constructed based on the patient's data or imaging. Therefore, it is critical to include the patient's CT scan inside the virtual world, as shown in Figure 3C. Digital or virtual simulation offers several advantages which are sometimes difficult to implement in the real world. For example, in this project, the user can temporarily hide the patient anatomical structure by using the controller's B button. Therefore, the user can focus on the mandibular arch (Figure 5A). Our project also offers a feature to adjust the mandibular arch's transparency with the right thumbstick (Figure 5B).

The project's focus is to provide a simple and intuitive interaction for learners in order to lessen the learning curve and reduce adaptation time. In contrast to the existing software that still depends on the conventional windows-icon-mouse-pointer (WIMP) approach, Quest's controllers offer interaction which makes it more realistic. Therefore, the digital version's skill can be utilized when the user performs an actual implant procedure. In this

project, the user needs to click and hold the right trigger button to grab the tools, such as a surgical knife and hand piece (Figures 6A and 7A).

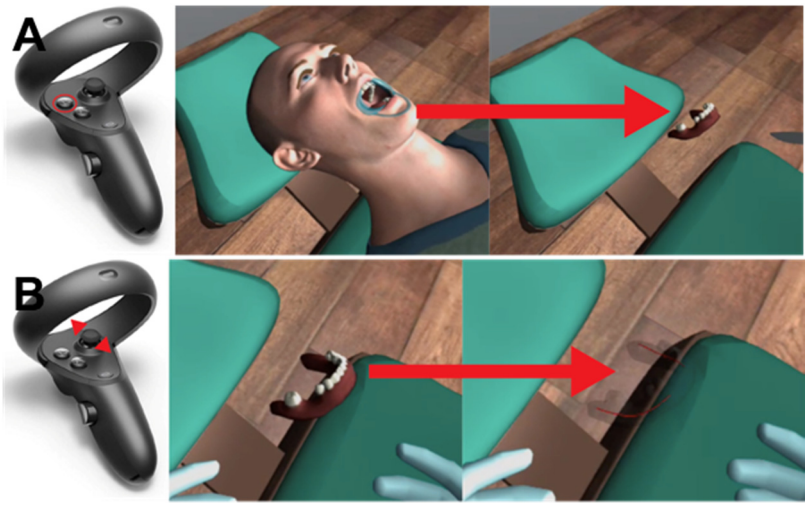

Figure 5. (**A**) "Hide patient" feature, (**B**) adjusting lower jaw's transparency.

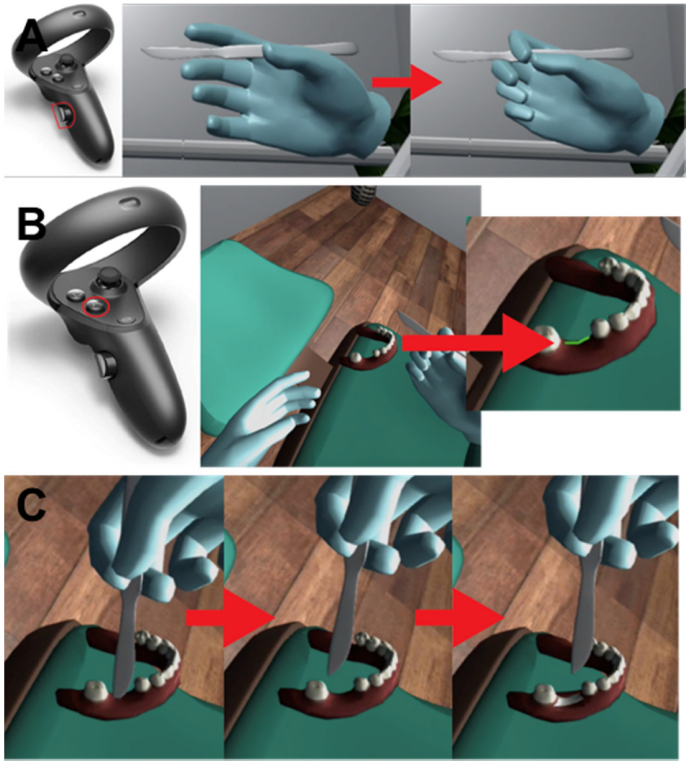

Figure 6. (**A**) Hold trigger button to grab surgical knife, (**B**) activating the incision guideline (**C**) incision procedure in our project.

The dental implant procedure begins by incising the patient's gingiva with the scalpel. Figure 6A depicts how the instruments are grasped and positioned. For learning purposes, an incision guideline has been provided for the user to be activated by hitting and holding the A button (Figure 6B). If the incising procedure is appropriately performed, the gingiva will be reflected, and the mandibular bone will be exposed (Figure 6C).

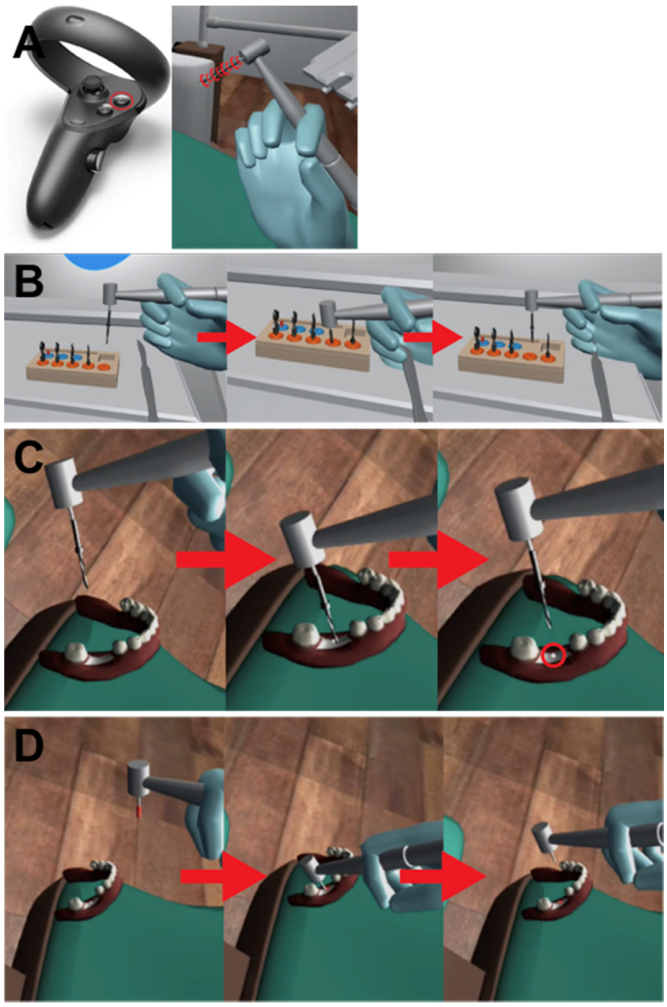

Figure 7. (**A**) Y button to spin the drill, (**B**) switch the drill, (**C**) drill process in this project, and (**D**) implant placement process in this project.

After reflecting the surgical flap and exposing the bone, the osteotomy is initiated with twist drills. To perform this procedure, the user needs to hold the drill and then click the Y button on the left controller to spin the drill (Figure 7A). The user can also pick a different size of twist drill, and switch the twist drill to a different size (Figure 7B). The drilling process in this project can be seen in Figure 7C. When it combines with the transparency adjustment, the user can estimate the drill's depth to avoid the critical anatomical structure, the inferior alveolar nerve. Finally, the next step is to place the implant (Figure 7D).

2.2. Students' Perception of the VR Implant Surgery

The protocol of the study has been approved by the UIC-IRB office (Exempted). Seven dental students enrolled in the Advanced Predoctoral Implant Program (APIP) were invited to participate in the study. The survey was created based on Goodacre [20] and Pulijala et al. [9] with some modification. The first survey (18 questions) and second survey (8 questions) inquired into the applicability and usability of the VR program in the curriculum, respectively. First, each participant was asked to fill out the first survey of 18 questions (pre-test) prior to using the program. Then, each participant was shown a video describing the controls of the program. One of the authors demonstrated those instructions using the program with the screen casted onto an iPad to show the individual using the program and the screen the individual was viewing. Next, each participant used the headset and controls to explore the program while the program was casted onto an iPad to assist them in using the program. After each participant felt comfortable with

the program and explored it for 10–15 min, they took the headset off and completed the same first survey again (post-test) with an additional 8 questions. Data were entered and analyzed in the Microsoft Excel sheet. Descriptive statistics including the frequencies and mean values were analyzed.

2.3. Focus Group Discussion (FGD)

To investigate the student experience and perception regarding this new pedagogy, we conducted a focus group discussion (FGD) via an online platform (Zoom Video Communications, Inc., San Jose, CA, USA). FGD questions targeted 4 domains: opinions about the immersive experiences, the advantages and disadvantages of this project, features to add or delete in this project, and the future of dental education using VR.

3. Results

All seven senior students in the APIP voluntarily participated in the study including the focus group discussion, therefore, the response rate was 100 percent. In this project, we only focused on the APIP students because they are the cohort of students who have the opportunity to perform implant surgery in the College of Dentistry. Detailed information regarding APIP has been described previously [21].

3.1. Students Perception on the VR Implant Surgery

With regard to student perception on the applicability of the VR program to the curriculum, overall, the perception was increased approximately 1-fold in the post-test except for 2 questions: "I think I would prefer traditional lectures over use of the VR in class" and "I believe that the VR should be used without any classroom discussion" (Table 1). For students' perception of the usability of the VR program, students reported high scores (>4) on all factors with the exception of two questions: "I could not tract my hands in the application accurately" (lowest score) and "I did not experience nausea, dizziness, or headache using this VR application" (Table 2).

Table 1. Students' perception regarding applicability of the VR program to the curriculum (1 Strongly disagree–5 Strongly agree).

	Pre Mean ± SD	Post Mean ± SD
I found this "VR" application very interesting.	4.3 ± 0.5	5.0 ± 0.0
I think the use of "VR" has aided my learning of implant surgical placement.	3.9 ± 0.7	4.6 ± 0.5
I think I would prefer traditional lectures over use of the "VR" in class.	3.0 ± 0.8	2.9 ± 1.3
I believe that the "VR" should be used without any classroom discussion.	2.3 ± 0.5	2.6 ± 0.5
I think the use of the "VR" encouraged me to actively participate more in class.	3.3 ± 0.5	4.3 ± 0.8
I am very interested to use the "VR" outside of class.	4.0 ± 0.0	4.9 ± 0.4
I think the "VR" helped me develop my three-dimensional visualization skills (ability to visualize three-dimensional shapes).	3.3 ± 0.5	4.6 ± 0.8
I benefitted from the imagery and visualizations of implant surgical placement that the "VR" provides.	3.7 ± 0.8	4.9 ± 0.4
I think use of the "VR" improved my enthusiasm and motivation toward learning.	3.6 ± 0.5	4.7 ± 0.5
I think the "VR" provided easier access to learning materials than traditional lectures and textbooks.	3.4 ± 0.5	4.4 ± 1.0
I think the "VR" helped me to prepare for clinical applications of implant surgical placement.	3.6 ± 0.5	4.7 ± 0.5
I think I can use the "VR" as supplement to the traditional lectures.	3.9 ± 0.4	4.9 ± 0.4
I think the "VR" can provide outstanding visualization that isn't possible in the traditional classroom.	3.9 ± 0.7	4.9 ± 0.4
I think the "VR" increases students' engagement via an immersive experience.	4.0 ± 0.0	4.9 ± 0.4
I think the "VR" can enhance my education through "learning by doing it".	4.1 ± 0.4	4.7 ± 0.5
I think this "VR" application will increase the confidence of surgical trainees before they perform a real surgery in the operating room.	4.0 ± 0.6	4.9 ± 0.4
I want to see more implant treatment procedures developed into VR procedures.	4.1 ± 0.9	5.0 ± 0.0
I think the "VR" can improve the quality of implant education in general.	4.1 ± 0.4	4.9 ± 0.4

Table 2. Students' perception regarding usability of the VR program (1 Strongly disagree–5 Strongly agree).

	Mean ± SD
I found the headset comfortable to wear throughout the application usage.	4.3 ± 0.5
I found the quality of the audio to be excellent.	4.0 ± 0.6
I found the quality of the images to be excellent.	4.1 ± 0.7
I could interact with the user interfaces as I expected.	4.3 ± 0.5
I could touch the virtual objects appropriately.	4.6 ± 0.5
I could not tract my hands in the application accurately.	1.9 ± 0.7
I did not experience nausea, dizziness, or headache using this "VR" application.	3.6 ± 1.3
It was comfortable to use the "VR" surgery application.	4.4 ± 0.5

3.2. FGD Result

3.2.1. Student Perceptions of Immersive Experiences

All students believed that this application could be helpful as a supplement to student learning. Some students believed that the immersive experience could distract the students from the goal of the program. One suggestion was to limit the interactive environment in the VR to limit the distractions. For example, to limit the amount of decor in the virtual office or prohibit non-essential accessories from working, such as the computer or desk chair. The students explained that the "feeling" of being in the clinic environment was useful and could be useful for practicing small details of a procedure. Examples discussed were the ability to practice ergonomic position when treating specific teeth/quadrants. The overall student consensus was that the virtual reality experience has the potential to work as a supplemental resource for particular components of specific subjects which will be further discussed in the results.

3.2.2. Advantages and Disadvantages of VR

Students expressed that the cost of the Oculus headset could be a limitation if students were to purchase them, but would not be as much of a burden if the University was to purchase them. Some disadvantages discussed by students were the difficulty in accurately reproducing dental procedures. Some students explained that they felt the program would not accurately represent hand skills for procedures such as crown preparations due to the detail incorporated into that procedure and limitations of the hand controls of the oculus. Most students agreed that the VR program would aid in learning the sequence of procedures. One student explained how it would assist in the steps of implant preparation and placement which can be complex for novel learners.

3.2.3. Features to Add or Delete from Application

All students unanimously agreed that they prefer the program to be more interactive. Specific examples discussed were being able to adjust the patient's headrest, the overhead light, tilt the patient's head, and adjust provider chair positioning. The students unanimously agreed that the haptic feedback utilized with the drill and scalpel should be applied for many of the tactile sensations, such as touching the patient or just grabbing the handpiece. One student explained how the height setting may have been too high for her at times and there was no option for her to sit down in a chair as an operator. Another student expressed how zooming in on certain aspects such as the mouth can provide a more detailed experience. This student also suggested adding challenges to scenarios such as the patient's tongue, blood, or saliva being present to be more realistic. Another student proposed that using the VR program as a supplement prior to the hands-on pre-clinical simulation could be useful, especially due to new social distancing limitations.

3.2.4. VR in the Curriculum and VR as the Future of Dental Education

The general consensus was that VR is the future of dental education, especially due to the COVID pandemic and its limitations on in-person learning. Students expressed that

the accessibility of the VR is one of its main attributes. Students do not need to be in the physical presence of faculty yet, still receive feedback. One student stated that while "it's a good way for students to practice at their own houses or apartments, I don't think it could replace the hands-on clinical experience. But it's a step in the right direction". All students unanimously agreed that VR should be used in specific ways as a supplemental resource in dental education. Students described that VR could be used to visualize 3D anatomy as a step above the iPad applications that currently exist for dental anatomy. Students agreed that station exams can be utilized through VR and provide a standardized field for all students to interact with the test material without having to worry about damaging it, so every student has the exact same case. Other subject matters offered by students were cardio pulmonary resuscitation, basic life support, and emergency situations. Students pointed out that being physically present in the environment of an emergency could better prepare them for emergency situations without having to act it out. Students also suggested that this program can be a useful tool in endodontics teaching since they often found it difficult visualizing what faculty are trying to teach with 2D pictures.

4. Discussion

This article described the development of immersive virtual reality for dental implant education by using Oculus Quest. The VR headset is designed to block the user's peripheral view, replace it with a synthetic environment, and immerse them into the new "world." Although these protocols are relatively efficient in increasing the user's presence inside the virtual environment, it also creates an "isolation" vibe. VR provides a rich three-dimensional virtual environment. VR offers the learners an opportunity to participate in a virtual environment to interact with a target, and build, view, relay, and receive information. [22] This allows social interaction without being physically in the same environment. VR also provides an option to visualize difficult models. [23] In dental education, some topics are challenging to visualize/conceptualize. For example, teaching of occlusion and its related topics can benefit from this technology.

Traditional lecture-based education tends to disengage students, causing students' dissatisfaction, frustration, and negative experiences [24]. The pedagogy in dental education has adapted and shifted from traditional lectures and analog pathways, to including digital workflow/technologies [1–3,5] and VR approaches. VR leads to an increased student engagement. VR can transport students to a new virtual environment. In this application, students were completely immersed and engulfed with the virtual dental operatory which provided a much more exciting learning experience than learning in the traditional lecture room or preclinical exercise room [25,26]. This excitement can spark interest in the subject and improve class discussion and student engagement [23]. Further, VR also has the potential to enhance educational platforms by creating an immersive learning environment which is customizable and has no time or distance barrier. Students can also learn at their own pace [23]. VR may also be beneficial for distance and shy students [27]. During the COVID pandemic, many students are learning from home. With this technology, they can still participate in the class from their home. The immersive environment in VR also helps students apply their knowledge, values, and skills in a safe environment [22].

Simulation has been used to enhance knowledge, clinical skills, and clinical decision-making, particularly in high stakes procedures. Implant dentistry is a high stakes procedure and thus far, the most common educational approach to train surgeons is by placing implants in the typodont. VR simulations provide dental students and residents with the opportunity to perform high-risk and high-cost treatments on virtual patients and gain experience without endangering the safety or real patients. In this VR application, the case can be customized according to the patient's Cone-Beam Computed Tomography CBCT information, which allows surgeons to practice and rehearse surgeries using patient scans in a realistic and zero-risk virtual reality environment. Further, VR also provides an opportunity for learners to keep practicing without fear of making mistakes and harming patients.

Our study suggests that after experiencing immersive VR, students displayed positive attitudes toward the applicability and usability of VR in dental implant curriculum after comparing pre- and post-test assessments. Two questions: "I think I would prefer traditional lectures over use of the VR in class" and "I believe that the VR should be used without any classroom discussion" did not improve and improved only minimally in the post test. The results may suggest that VR can be used as an important adjunctive tool to enhance the traditional curriculum.

The FGD also described the students' perception in a rich, comprehensive, and detailed manner. Some advantages, disadvantages, and their expectations were discussed. In the FGD, some students were concerned regarding the price of the devices. The price tag for untethered VR headset currently is starting from $299 which is significantly cheaper than the virtual dental simulator that can cost around $100,000 per device. Similar to any other electronic devices, the price will become more affordable over time.

The students indicated both from the survey and the FGD that the use of the Oculus Quest Controller does not truly simulate the clinical hand movements. With our current technology, some limitations of the program were noticed. For example, the operator cannot feel the weight of the hand piece and the tissue density when using rotary and surgical instruments. However, some improvements are warranted to overcome the limitations. Currently, we are investigating a glove controller that more accurately fits with our project and can provide a haptic feedback element to improve the overall learning experience.

Pantelidis in 2009 proposed a 10-step model for determining when to use virtual reality in education and training courses [28]. In step 7, she proposed that the virtual application should be evaluated using a pilot group of students. In this study, we only have a limited cohort participating in the study. We invited only 7 senior students from the APIP. The result may not be indicative of the perceptions of the entire class of dental students. However, in our institution, senior students have been exposed to extensive clinical procedures, including implant restoration. Additionally, only APIP students are allowed to perform implant surgery; therefore, we strongly believe that their opinions present an accurate representation of the dental student perception. Furthermore, the rich descriptions of student beliefs and perception from the FGD will be of interest to improve the application and to dental educators considering VR adoption in the future of dental education.

Currently, we are working on the multi-user virtual environment (MUVE) application. The use of MUVE in dental education may stimulate collaborative work between instructor-student and student-student. MUVE may offer the opportunity for more intense participation compared to the traditional asynchronous setting [29]. The ability to interact with other users may significantly increase learners' motivation. The student can discuss and collaborate in a virtual environment. Simultaneously, the teachers can emotionally connect with students via voice and gesture and provide more realistic feedback, just as they would do in the in-person classroom.

5. Conclusions

In this study, the development of an immersive virtual reality program for dental implant education using Oculus Quest was described. The advantages and disadvantages of the current application were presented and discussed. Some limitations and future directions on different approaches to improving its development and applications were proposed. This application can offer learning and teaching opportunities in the preclinical curriculum and exercises, especially during these challenging times.

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