Extended Reality in the Operating Room: Robot-Assisted Orthopedics Surgery with Live and Interactive Streaming for Medical Students

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Abstract: Traditionally, medical education comprises both theoretical learning in classrooms and clinical training in hospitals where students can gain clinical experience. This is mostly done on face-to-face teaching models, focused on the educational philosophy of "see one, do one, teach one", was the standard teaching methodology in medical education. Medical education is transforming thanks to medical schools adopting innovations to new clinicians, such as immersive prepare techniques (extended reality): virtual reality, augmented reality and virtual reality. Immersive learning technologies, such as extended reality, can provide an engaging and interactive platform to generate a stimulating learning environment and with the recent development and increased accessibility of immersive technologies, educators have the potential to make simulation-based training more effective. By using holographic devices, such as Microsoft HoloLens 2®, and 5G wireless communications we intent to explore the innovative experience of a robot-assisted orthopaedic surgery, where the procedures were transmitted live stream to Pregraduate Medical Students using the Microsoft Remote Assist®. In addition, students had the opportunity to interact directly from a classroom to the operating room, asking to the surgeon about the procedures performed during surgery and get involved in the surgery, even remotely. At the end, students completed a questionnaire to evaluate the experience and the preliminary results made possible to assess the effectiveness of this experience and identify areas for improvement for future surgery transmission, revolutionizing the teaching and practice of surgery.

1 Introduction

Medical knowledge is changing rapidly: medical knowledge doubles every 6–8 years, with new medical procedures appearing every day. The rapid change in medical knowledge calls for innovative learning tools for medical practice and education. Immersive technology seems to be one of them (Tang et al., 2022). Traditionally, medical education comprises both theoretical learning in classrooms and clinical training in hospitals where students can gain clinical experience (Van Way, 2017). This is mostly done on face-to-face teaching models, focused on the educational philosophy of "see one, do one, teach one", was the standard teaching methodology in medical education (Viglialoro et al., 2021).

Medical training is a long and demanding process, in which the first stages are usually based on two-dimensional, static, and unrealistic content. Conversely, advances in preoperative imaging have made it an essential part of any successful surgical procedure (Sánchez-Margallo et al.,

2021). E.g., although cadavers constitute the gold standard for teaching anatomy to medical and biomedical science students, previous benefits have also been reported through the use of tablet-based software and new immersive technology (Sánchez-Margallo et al., 2021). Simulation-based training, relying on "see one, simulate many deliberately, do one" principle, has been proposed as an excellent adjunct method to traditional medical education (Stefanidis et al., 2015), (Vozenilek et al., 2004). However, due to COVID-19 pandemic there has been a recent shift to the greater adoption of technology in medical education (Haroon et al., 2020) and medical education has benefitted from the introduction of new technology within recent years such as immersive devices (Jacobs and Rigby, 2022). Medical education is transforming thanks to medical schools adopting innovations to new clinicians, such as immersive prepare techniques: virtual reality, augmented reality and virtual reality (Yasser, 2019).

Mixed Reality (MR) was first mentioned in 1994 by Paul Milgram, and is a blend of physical and digital worlds, unlocking the links between human, computer, and environment interaction, is based on advancements in computer vision, graphical processing power, display technology, and input systems (Microsoft, 2021). By using holographic devices, such as Microsoft HoloLens 2, the participants could take advantage of the ability to place digital content in the real world as if it were there. This technology allows participants to see through display and see the physical environment while wearing the headset and allows a full six-degrees-of-freedom movement, both rotation and translation. The participants can hold "hands-free" and "heads-up" teams video calls with experts anywhere in the world, with all of benefits in this kind of experience (Microsoft, 2021), (Gallagher and Alford, 2020).

Virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR) are examples of immersive technologies that have the potential to improve medical practice and education (Tang et al., 2022). In surgical training, most simulation-based approaches have focused on traditional VR and AR technologies, which offer different degrees of immersive experience but are generally unable to interact with 3D information combined with the real-world environment (F.M. et al., 2018), (Sappenfield et al., 2018). MR techniques have replaced these traditional technologies intending to combine the real working environment with virtual content so that users can interact with both simultaneously. MR surgical simulators and medical training applications are becoming an important part of the training process for physicians, as they allow for a training environment appropriate for recreating realistic and reproducible scenarios without putting the patient at risk (Amparore et al., 2022).

Recent research has also shown that with the use of advanced technological solutions such as MR, the spaces of the operating rooms tend to decrease and the number of professionals and students present during a surgery too (Anjali and David, 2018), improving the efficiency in the use of resources in a hospital, whether they are human, of space, or technicians and materials. MR is a concept which provide an "ideal virtual space with [sufficient] reality essential for communication" (Milgram and Kishino, 1994) . The combination of computer processing, human input, and environmental input sets the stage for creating true MR experiences. Movement through the physical world translates to movement in the digital world and improve the experience and better outcomes of the participants and tasks (Flavián et al., 2019), once it did not blind doctors' original view of the real world, but shows a new vision with mutual correction function, which improved the safety of surgery (Hu et al., 2019). This kind of technology is also a powerful for better training and improving education on surgical tactics and methods (Zhu et al., 2014).Medical teaching, due to the limitation of medical environment and ethics, as well as the teaching cost has been increasing, is limited (Hu et al., 2019). MR technology helps students to understand more intuitively the complex anatomy of the human body, which enables students to get more effective training. MR provides new learning models in medical education, which will transform the pedagogy from using two-dimensional images and video to promoting learning through interactive mobile environments (Sappenfield et al., 2018).

Surgical training outside the operating room (OR) using simulation has widely spread this last decade, especially in laparoscopic surgery (Reznick and MacRae, 2006) and training out of the OR has proven its positive effect in basic skills during real laparoscopic procedures in

patients. Such training out of OT may reduce learning curves and improve patients' safety in the OR. Indeed, juniors surgeons have limited access to these complex procedures as primary operator (Miskovic et al., 2010). In conclusion, medical education is transforming thanks to medical schools adopting innovations to new clinicians, such as immersive prepare techniques (extended reality): virtual reality, augmented reality and virtual reality.

2 Methods

To assess the utility of Mixed Reality (MR) in surgical medical education by the using of holographic devices, such as Microsoft HoloLens 2®, and 5G wireless communications a MR set up during an orthopaedic surgical lesson was prepared to explore the innovative experience of a robot-assisted orthopaedic surgery, where the procedures were transmitted live stream to Pre-graduate Medical Students. Instead of regular teaching (Figure 1), in a classroom distant from the real operating room with the share of slideshows and anatomical parts of the body, a surgeon who is also a professor of surgery, guided the students throughout the surgery using mixed reality glasses and the application Microsoft Dymanics 365 Remote Assist® (Figure 2). In addition, students had the opportunity to interact directly from a classroom to the operating room, asking to the surgeon about the procedures performed during surgery and get involved in the surgery, even remotely (Figure 2). At the end, students completed a questionnaire to evaluate the experience and the preliminary results made possible to assess the effectiveness of this experience and identify areas for improvement for future surgery transmission, revolutionizing the teaching and practice of surgery.

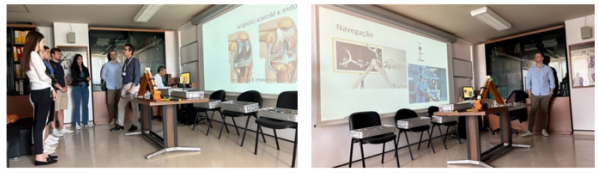

Figure 1: Regular Lesson.

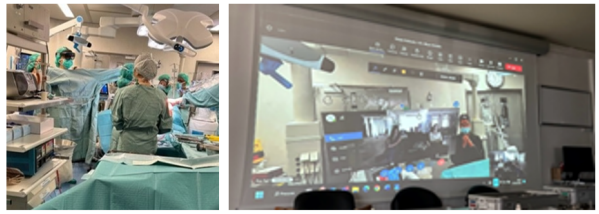

Figure 2: Mixed-Reality Lesson.

3 Results

The state of art review of the literature allows to verify that the growth of RM-assisted medical education and surgical practice are driven by advances in hardware and software, but they are yet underexplored. Real-time intra-operative guidance is a key for surgical precision.

Immersive learning technologies can provide an engaging and interactive platform to generate a stimulating learning environment (Barrie et al., 2019) and with the recent development and increased accessibility of immersive technologies, educators have the potential to make simulation-based training more effective. After analyzing the results from the perspectives of

the medical students it is possible to conclude that:
1. The quality of the video allowed a clear and detailed visualization of the surgery;
2. The quality of the sound allowed clear hearing of explanations and instructions during surgery;
3. The transmission of surgery through Hololens 2 and the Remote Assistant application facilitated the understanding of surgical procedures;
4. The ability to ask questions during the surgery live transmission made surgical procedures easier to understand;
5. The real-time interaction with the assistant surgeon through the remote assistant application was effective in answering students' questions;
6. The transmission of surgery using Hololens 2 and the Remote Assistant application promoted a greater interest and involvement of the medical students compared to traditional teaching methods;
7. The experience of watching the surgery through the Hololens 2 and the Remote Assistant application was very satisfactory for the medical students.

4 Conclusion

The emergence of new technologies is bringing new models of medical education. The development of MR systems has proven to be an important tool in supporting medical teaching and training. In fact, MR-assisted surgical education and practice is likely to undertake a greater role in the near future. As MR is now affordable, usable, acceptable, and increasingly well-validated, more future studies focus on efficacy of MR in enhancing surgical education and practice are needed and the MR availability needs to be increased. Moreover, MR expands the capabilities and effectiveness of remote learning, which was normalized during the COVID-19 pandemic, to ensure effective student and patient education. MR-based lessons, or even select modules, provide a unique opportunity to exchange experiences inside and outside the medical community.

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