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Comparative Analysis of HoloLens 2 and Apple Vision Pro in Orthopedic Surgery

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Abstract

The integration between 3D printing technologies and extended realities (XR) has revolutionised surgical practice. XR technologies include Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). All of them have optimised the planning and execution of surgeries through three-dimensional visualisations of anatomical structures in real time.

In this study, HoloLens and Apple Vision Pro technologies were compared in a pelvic chondrosarcoma implant surgery. During the procedure, the XR devices enabled surgeons to access real-time planning, improving accuracy and reducing operating room time.

Keywords: 3D surgery; Extended Realities; Implant; HoloLens 2; Apple Vision Pro; Orthopedic; Biomodel; 3D printing

Introduction

Digital health encompasses the use of digital technologies to enhance the efficiency of healthcare delivery, improve patient outcomes, and facilitate health management. Hospital General Universitario Gregorio Marañón (HGUGM) is at the forefront of integrating digital health technologies into surgical practice through the 3D Manufacturing and Advanced Planification Unit (UPAM3D).

The UPAM3D is a point-of-care unit which combines different technologies from 3D printing to surgical navigation, significantly exemplifying the principles of 5P medicine—Predictive, Preventive, Personalized, Participatory, and Precision medicine [1,2].

In recent years, Extended Realities (XR), which includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), has revolutionized the healthcare industry.

The integration of extended reality technologies in surgery represents a significant milestone in the field of digital surgery. These technologies are fundamentally transforming how surgical procedures are planned and executed, greatly enhancing precision both in preoperative planning and intraoperatively.

Specifically, mixed reality and holographic devices are introducing notable innovations in surgical practice by enabling detailed, real-time 3D visualization of anatomical structures. This capability not only facilitates more precise planning but also integrates diverse sources of information directly into the surgical workflow, thereby optimizing clinical outcomes and minimizing associated risks [3].

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The UPAM3D is working on a real integration of this technology within its process map together with its different services already offered (3D printing, digital planification, surgical guides and implant design). To reach that objective, the group has worked with different XR devices such as HoloLens 1, HoloLens 2, MetaQuest 2 and, more recently, Apple VIsion Pro.

This paper explores the evolution, current state, advantages, disadvantages, risks and opportunities of XR technologies in healthcare, focusing the analysis on orthopedic and traumatology surgery. We compare key devices such as the Apple Vision Pro and HoloLens 2, highlighting the hardware advancements that drive these experiences and their unique features, capabilities, and applications in the medical field. By examining technological innovations and market trends, we aim to provide a comprehensive overview of how XR is reshaping healthcare.

Technologies and Devices

The advances and progress of the recent years in XR technologies offer innovative methods for patient care, medical education and surgical operations [4-7]. By blending real and virtual environments, XR creates immersive experiences that open up new possibilities for enhancing medical results and elevating patient care.

VR, AR and MR

VR technology creates immersive environments, which block out the surroundings and make the user disengages from reality. This technology is often used for practicing complex surgeries and supporting pain management and physical therapy through engaging simulations [8,9].

AR integrates digital information with the physical world. This technology projects holographic images and data directly into the user's line of sight. This capability proves especially advantageous in surgical environments, where AR provides real-time anatomical overlays and essential data, thereby minimizing errors, enhancing patient outcomes and improving the accuracy and effectiveness of medical procedures [4,5].

MR combines aspects of both VR and AR, creating hybrid environments where digital and physical elements seamlessly interact in real-time. This technology offers sophisticated spatial awareness and precise hand tracking capabilities. These advancements enable healthcare professionals to visualize and manipulate 3D medical images directly within surgical environments, thereby enhancing diagnostic accuracy and facilitating personalized treatment plans [6,7].

The different technologies explained above can be offered by different devices, although some devices are much more versatile than others. VR devices include the Oculus Rift, HTC Vive, and PlayStation VR. In AR, notable devices are Microsoft HoloLens and Google Glass. MR combines elements of VR and AR, with devices like HoloLens 2 and Magic Leap.

See-through and pass-through

See-through technology in augmented and mixed reality employs transparent lenses that allow direct viewing of the real environment, superimposing holograms through optical waveguides. This method ensures high fidelity in the perception of the real world. While it offers natural interaction and low latency due to the absence of real-time video processing, it is limited by the resolution and brightness of the virtual elements and less effective in bright lighting conditions [10].

Conversely, pass-through technology has cameras to capture the real environment, projecting it onto screens in front of the user's eyes where virtual elements are blended with the real-time video feed. This approach allows for high-resolution and advanced visual effects, enhancing the integration of virtual elements irrespective of lighting conditions. However, it introduces higher latency due to continuous video processing and consumes more energy, with a less natural perception of the real environment compared to see-through technology [11]. The principal disadvantage of this technology to be used in medical procedures is the risk of running out of battery life, as this fact supposes a complete sight and real life perception loss.

Devices working with see-through technology can only offer AR and MR applications due to their hardware. However, pass-through devices have the ability to offer all three types of applications within extended realities (VR, AR and MR) and the versatility of exchanging between each other while the device is being used.

HoloLens 2 vs Apple Vision Pro

The Microsoft HoloLens 2 and Apple Vision Pro are both advanced extended reality devices but with different features.

HoloLens 2

HoloLens 2 uses see-through technology. It features holographic lenses with a 2K resolution per eye, offering a 52-degree field of view. This device supports intuitive interactions through hand tracking, eye tracking, and voice commands. It is a self-contained unit with a flip-up visor, providing 2-3 hours of active use. HoloLens 2 runs on Windows Mixed Reality and integrates seamlessly with Microsoft's suite of enterprise tools, such as Azure and Dynamics 365, making it invaluable in sectors like manufacturing, healthcare, and education for remote assistance, complex assembly, training simulations, and 3D modeling [12].

Apple Vision Pro

In contrast, Apple Vision Pro uses pass-through technology and is designed for a broader audience, encompassing both consumer and professional users. It boasts dual 4K micro-OLED displays, providing exceptionally high resolution and pixel density. Its field of view has not been specifically disclosed. Interaction with the Vision Pro is facilitated through advanced hand tracking, eye tracking, and voice commands, and it integrates seamlessly with Apple's extensive ecosystem, including iOS and macOS. The device features a sleek and lightweight design focused on user comfort, with an external battery pack allowing up to 2 hours of use, and can also be used while plugged in. Running on visionOS, the Apple Vision Pro is able to deliver a wide range of immersive experiences, from productivity and collaboration tools to entertainment and gaming [13].

Feature	HoloLens 2	Apple Vision Pro
Display Type	MEMS Display	Micro-OLED
Resolution	2048 x 1080 per eye	23 million pixels
Weight	566 g	650 g
Battery Life	2-3 hours	2 hours
Processor	Snapdragon 850	M2 nad R1
Price	3,849 €	3,999 €

Digital orthopedic surgery

Background

The 3D Printing Unit at Gregorio Marañón Hospital applies the point-of-care (POC) design and manufacturing model to stimulate collaborative work between clinicians and engineers. This approach generates team-based knowledge and establishes local quality controls and surveillance to develop personalized, safe solutions. 3D printing within a hospital represents a paradigm shift, overcoming limitations of traditional industry-based manufacturing for customized medical products. However, adherence to regulatory compliance and quality management standards is crucial. The UPAM3D is committed, among its core functions, to advocating for patient safety by ensuring the quality of these unique personalized products. Gregorio Marañón Hospital distinguishes itself by integrating an efficient quality management system compliant with the international standard ISO 13485 for medical devices [1,14].

Since 2014, when UPAM3D started its first steps, this unit has been validating the integration of 3D technology in the workflow of a university hospital: 3D reconstruction, 3D computer-aided planning, 3D printing and XR [1].

The integration of 3D planning software significantly enhances the safety of surgical interventions. Additionally, 3D printing technology contributes substantial value to this planning phase, as surgeons utilize patient-specific replicas to custom-mold standard implants according to patient's unique anatomy. These technologies are not confined to the preoperative stage alone; the fabrication of surgical guides allows the meticulous preoperative planning to be seamlessly transferred into the surgical environment. This workflow is currently being extended to incorporate XR technologies, aiming to transfer and apply the entire planning process directly into the intervention room, thereby enhancing surgical precision and outcomes.

The trend in recent years is focused on using the computer-aided planning not only as a preoperative application but also in the operating room, transferring all this planification to the highlights of the intervention.

The research developed through years by the Orthopedic Surgery and Traumatology Department together with UPAM3D in the field of Extended and Digital Surgery suppose a wide knowledge about advantages, disadvantages, risks and opportunities of the integration of these technologies into the clinical practice.

Clinical cases

Next, as an example of the use of the devices, a clinical case of a hemipelvis implant for chondrosarcoma carried out by the Orthopaedic Surgery and Traumatology Department in collaboration with UPAM3D engineers will be presented.

Hemipelvis implant for chondrosarcoma

The surgical intervention consisted of the placement of a customised implant designed to be anchored by a stem into the iliac crest and an acetabular component with the ability to slightly elevate the centre of rotation. The design included three screws strategically oriented from the dome to areas of increased bone stock to ensure stable and functional fixation (Figure 1).

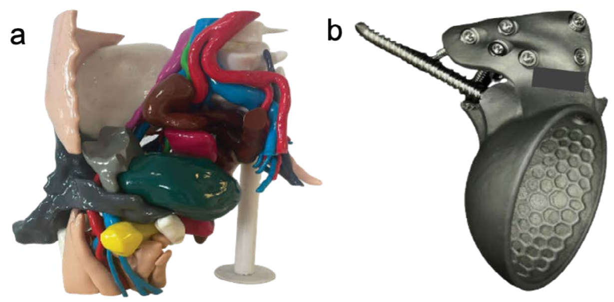

Figure 1: (a) Printed biomodel. (b) Ti6Al4V implant and screw.

The surgery presented multiple challenges due to the patient's clinical conditions, which included a history of recurrent infections, extensive fibrosis and significant bone resorption. These complications not only made the surgical approach difficult, but also increased the complexity of implant placement, given the proximity of critical structures such as the iliac artery, iliac vein and sciatic nerve.

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Figure 2: Surgeons using the devices in the surgical field.

To address these difficulties, extensive preoperative planning was performed based on high-resolution computed tomography (CT) images. These images were used to generate accurate three-dimensional models to simulate the surgery and design the customised implant. In addition, the data was integrated into HoloLens 2 and Apple Vision Pro devices, which were used during the surgical procedure. Both devices provided the medical team with the ability to visualise preoperative planning in real time overlaid on the surgical field, facilitating accurate implant placement and minimising associated risks.

Conclusions

The integration of XR technology in surgery has proven to be a crucial advance in the accuracy and safety of interventions. The use of devices such as HoloLens 2 and Apple Vision Pro has highlighted how holographic visualisation and interdisciplinary collaboration improve surgical planning and execution, reducing procedure times and risks. These technologies not only optimize clinical outcomes, but also represent a significant advance in quality of care and medical education.

This comparative work identifies areas of improvement in the devices and their applications, differentiating one from the other in terms of the added value they offer at each step of the surgical lifecycle.

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