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Mixed Reality Improves 3D Visualization And Spatial Awareness Of Bone Tumors In Orthopaedic Oncology: A Proof Of Concept Study

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Abstract

1 Introduction

In orthopaedic oncology, computer navigation and 3D-printed guides facilitate precise osteotomies only after surgical exposure[1,2]. Visualizing virtual 3D models on the 2D flat screen of the computer station lacks depth perception and parallax compared to physical 3D models. Before surgeries start, it is challenging to mentally process and superimpose the virtual data onto patients' anatomy for surgical assessment. Mixed Reality is an immersive technology merging real and virtual worlds, and users can interact with digital objects[3]. Through Head-Mounted Displays (HMD), surgeons directly visualize holographic models that overlay tumor patients' anatomies in their physical environment before surgeries start. Clinical case reports of MR application are limited to spine and shoulder arthroplasty, and no data in orthopaedic oncology.

2 Methods

Between July 2021 and October 2022, we retrospectively reviewed eight bone tumor patients undergoing surgeries. There were six primary bone sarcomas, two benign bone tumors, and one revision pelvic prosthesis. The tumor locations were pelvis (three), tibia (two), proximal femur (one), scapula (one), proximal humerus (one), and calcaneum (one). Four patients underwent 3D-printed guideassisted bone resection. The MR software platform was developed (Syngular Technology Limited, Hong Kong SAR, China), and MR holographic application was prepared for each case. Polygons-based 3D bone-tumor models are generated from 2D CT +/- MRI images in DICOM format. Computer graphics software generates photorealistic, cinematic-rendered models. A 3D Engine (Unity Technologies, Unity Software Inc, San Francisco, US) was used to develop the User Interface for the holographic contents. The final holographic application was exported and loaded into the MR-HMD (Hololens 2, Microsoft Corporation, Redmond, WA, USA).

In the conventional 2D method, the surgeon studied 2D medical images and the planning of 3D-printed guides, then mentally overlaid the virtual 3D models onto the patients' bodies. In the MR technology group, the surgeons directly visualized 3D holograms on the patients' bodies via HMD (Figure 1). The surgical incision, approach, and sites of osteotomies were decided while examining the patients with both methods. There is no reported quantitative tool to assess the users' experience in spatial awareness of bone tumors as a preoperative assessment tool. Therefore, for each method, the surgeon completed a qualitative survey 1) a Likert-Scale (LS) questionnaire to assess his opinions on the spatial awareness of the bone structures and the effectiveness of surgical planning and 2) The National Aeronautics and Space Administration-Task Load Index (NASA-TLX) score to evaluate the surgeons' cognitive workload. The results of the two methods were compared using Wilcoxon Signed Rank Test for paired samples.

3 Results

The Likert-scale questionnaire revealed that the MR 3D hologram group was superior in surgeons' spatial awareness of 3D models and more effective as a preoperative planning tool than the Conventional 2D group. For NASA-TLX scores, the overall cognitive workload was significantly lower in MR 3D hologram group than in the 2D Group for preoperative clinical assessment. The MR 3D group received significantly lower "mental," "temporal," "performance," and "frustration" scores; however, they received significantly higher "physical demand" and "effort" ratings than the Conventional 2D group. Histological examination of the resected specimens showed that two of the five bone sarcoma patients had microscopic positive margins in the soft tissue. All bone margins were negative.

4 Discussion and Conclusion

The study may be a proof-of-concept for MR application in orthopaedic oncology despite limitations like few cases evaluated by a single surgeon evaluation, an immature platform for MR, and lack of objective assessment. MR technology potentially improves 3D visualization and spatial awareness of bone tumors in patients' anatomies and may facilitate surgical planning before skin incisions in orthopaedic oncology surgery. The results concurred with the first case series of MR applications during orthopaedic surgery [4]. With less cognitive load and better ergonomics, surgeons can stay focused on the patients and surgical tasks while keeping their hands free and sterile to manipulate virtual objects [5]. Further studies can investigate whether MR technology translates into better clinical outcomes. The clinical roles of other MR features, like instant access to medical data, remote assistance, guided osteotomies, and surgical training and education, could be explored.

5 References

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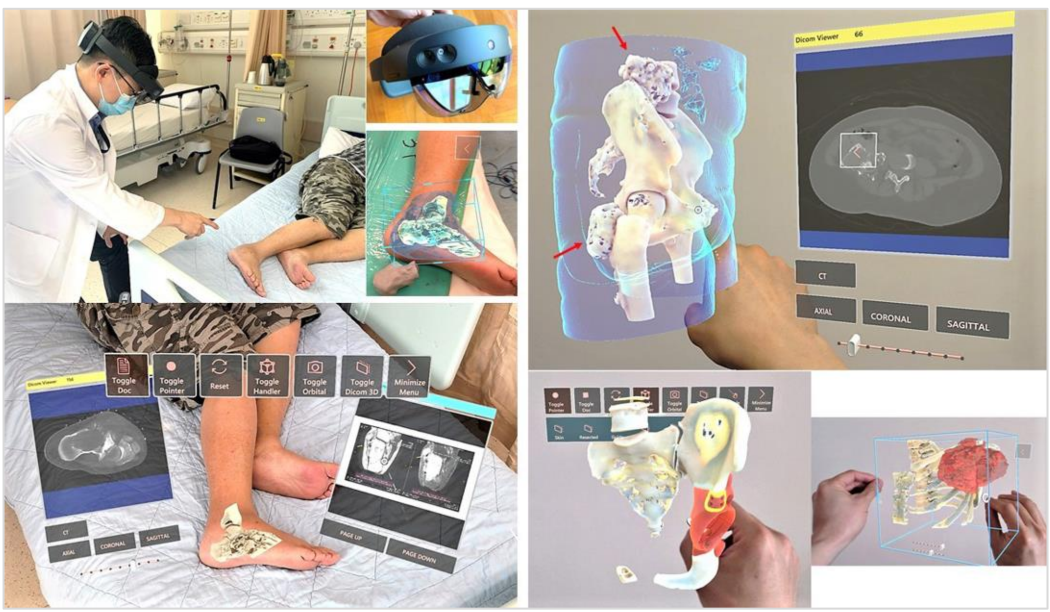

Figure 1: The use of mixed reality in Orthopaedic Oncology