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# Use of Hologram Application in Orthopaedic Surgery: A Critical Intervention and Modality.

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***Abstract*-- Surgery is a major domain of speciality, in which orthopedics is a specialized branch focusing on the diagnosis and treatment of musculoskeletal disorders, heavenly dependent on two-dimensional(2-D) imaging modalities such as X-ray and magnetic resonance imaging (MRI), which pose significant constraints on intraoperative precision. The introduction of holography and its integration with augmented reality (AR) and mixed reality (MR) technologies has introduced transformative possibilities in this domain. This review explores the fundamental concepts and principles of holography and highlights recent advancements in its application within orthopedics surgery, particularly in complex bone procedures like spinal and joint replacements, fractures. Holographic systems increase the surgical visualization, treatment planning, and intraoperative navigation, thereby improving accuracy, reducing complications, and optimizing outcomes. The paper also discusses the potential of holograms as educational tools and their future role in surgical intervention, emphasizing current technological limitations and the evolution of holographic applications in orthopedics.**

***Keywords*-- Bones, Hologram, Holography, Orthopaedics, Surgery.**

## I. INTRODUCTION

Orthopedics surgery is a divisional branch of medicine partially integrated with surgery that deals with the early diagnosis and treatment of musculoskeletal system disorders. It encapsulates various procedures, from joint replacement, fracture fixation, and spine surgeries to more advanced reconstructions[1].

Orthopedics surgery mostly depends on the two-dimensional introduced tools for imaging including X-ray and magnetic resonance imaging (MRI)[2]. One of the major challenges that appear during orthopedics surgery is intraoperative precision(2). Incorrect positional alignment of screws or plates, etc during the time of surgery can lead to post-operative complications, requiring major revision surgeries[3].

Surgeons sometimes also struggle with the limited field of view or faded depth perception while they are dealing with complex cases[4].

The term holography was coined by Dennis Gabor in 1948, and he got a Nobel Prize for this work(5). In 1962, the development of the recorded three-dimensional(3-D) object was done, which allowed the displaying of the required statistic objects. Holography sheds the idea of providing the whole picture in 3-D form, which allows the individual to look around and behind the projected object[5].

Holograms define the science and technology of creating 3-D images. The principle over which the holograms work is the principle of inference. By this principle, one set of film-forming waves is deflected onto the photographic film, by the object being imaged continuously, while another set of waves arrives at the film without reflecting from or passing through it[6]. The foundation of holograms had been laid before the early decades, but the recent advancements in the field of augmented reality (AR) and mixed reality (MR) have shaped the domain of hologram use.

The integration of holographic advancement in the domain of orthopedics surgery has significantly shaped the field, mostly in complex bone surgeries, surgical education, training, and pre- and intra-operative planning. In complex bone surgeries, mostly spinal and joint replacement procedures, 3-D holographic representations help the surgeons visualize bone constructions and the underlying structures in high detail. This modified aid in surgery ensures precise cuts and alignments, which are critical angles for the success of these intricate procedures [3].

The holographic integrative domain in orthopedics surgery holds promise for future modifications in procedural approaches during operations. This paper reviews about the current progress and modifications of the holographic approach in orthopedics surgery.

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## II. REVIEW OF LITERATURE

*Methodology:*

A wide array of searches was conducted over PubMed, Scopus, Web of Science, and Google Scholar. Search terms used were "Holograms"," Holography"," Orthopaedic Surgery"," Surgery", and" Bones". Initially, papers were selected based on the abstract. After that those papers that were related to orthopaedic surgery and holograms were included, and also those that were written in English. Exclusion criteria include those papers that were not consistent with the title and not written in English.

*Technological Foundation*

*Enhanced visualization and Surgical precision.*

The holographic system with mixed reality(MR) has shown its potential to enhance orthopedics surgery by improving visualization, treatment planning, and accuracy of the alignment. Lu et al., show that MR systems provide real-time integrative three-dimensional(3-D) holographic representations of patient anatomy, allowing surgeons to visualize the bones, ligaments, joints, and surrounding tissues with greater clarity[7]. Enhanced visualization is a crucial pillar in orthopedics surgeries, where the accuracy of anatomical structures and performed procedures during surgeries defines the outcome[5,7].

Furthermore, holograms also play a critical role in terms of treatment planning, by dynamically depicting bone fractures, lesions, or deformities and real-time intraoperative navigation. In a recent study, Bian et al. suggested that holograms can help surgeons achieve significantly precise implant placements, thus reducing major complications like misalignment and improper fixation[8]. It is also beneficial to show the non-contact, high-resolution 3-D images of bones and tissues, which are crucial and significant for understanding the complexity of fractures and early planning proper intervention[7].

The holographic imaging system also enhances our precision of the screw placements and majorly the surgical maneuvers, thus reducing the reliance on traditional imaging methods. In terms of the MR system, including Microsoft HoloLens, they show the real-time projection of holograms, which improves spatial awareness and communication among the surgical teams[7]. The latest HoloLens model has been promising in terms of showing a 25% improvement in augmented reality(AR) projection accuracy, further acting as the base pillar of the surgical setting[9].

These models help us in the pre-operative planning and ensure the critical angle of accuracy during surgical procedures, especially during complex surgeries such as spinal reconstruction and joint replacement.

*As a learning and stimulation tool*

The integration of holographic technology, with AR and MR, has changed surgical education. A recent study showed the potential use of AR training using Microsoft HoloLens, which significantly outperformed the basic traditional methods in teaching total knee arthroplasty, with the participants showing improved technical advancement and knowledge retention[10]. Furthermore, Liu et al. by using the MR system, demonstrated that real-time 3-D visualization of anatomical models holds promise for understanding complex surgical procedures and improving communication among the operating surgical teams[7].

*As an Intervention of Clinical Application*

Advanced holographic techniques are beneficial in orthopedics surgery for intervention planning, as they enhance the visualization of the anatomical structures and improve the procedural and treatment outcomes as demonstrated in the tertiary care center [11]. Furthermore, holography in medicine, including orthopedics surgery, allows visualization of the anatomical structures in early surgical planning, education, and telemedicine applications to enhance clinical outcomes[2].

Another approach through AR in orthopedics has demonstrated the potential benefits and outcomes in improving the safety and efficacy of clinical outcomes[12]. Furthermore, contactless measurement of fractured bones and surgical planning by an integrated approach of a holographic system and AR enhances the clinical outcomes and operating surgical procedures[2].

*Future Approach and Significance*

MR technology integrated with the holographic system shows real-time 3-D anatomical structures for enhanced visualization and close interaction, potentially improving the surgical precision and outcomes of the future[7,11,13]. Furthermore, real-time visualization, remote assistance, efficiency, and patient safety are its other critical components. It also aids the pre-surgical planning, intervention planning, and defect identification for significantly enhancing the surgical outcomes in the future after the treatment[13].

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The use of AR in orthopedics surgery shows the promise of decreasing cognitive load, operative time, and radiation exposure while increasing surgical precision, with future outcomes depending upon technological progress[14].

*Limitations*

The precision of the integrated holographic system, majorly affected by the environmental conditions and the requirement for accurate and cheap hand-eye calibration is a must for the effective procedural approach during the time of the surgery.

The use of HoloLens shows the practical use of systemic and effective approaches with enhanced clinical outcomes, but these devices have limitations in real-world use such as comfort and prolonged use[9].

Holographic systems in orthopedics surgery demand high cost, complexity, need for expertise, chances of potential misinterpretation, and the device validation need for precise and accurate bone 3-D visualization[4]. They also demand training of surgeons to operate the devices and extended use can lead to visual fatigue, which can hinder performance during the surgical procedures[9,15].

**Table I**
**Summary of the literature review and major findings.(MR-mixed reality)**

| Benefits: | Implication: | Citation: |
|---|---|---|
| Enhanced Visualization and Surgical Precision | Improved visualization of anatomical structures leads to more accurate surgical procedures. | [4,5] |
| Treatment Planning and Intraoperative Navigation | Holograms aid in planning treatments and navigating procedures, reducing complications. | [5] |
| Improved Surgical Accuracy | MR systems enhance the precision of surgical maneuvers and reduce reliance on traditional imaging methods. | [4,6] |
| Learning and Stimulation Tool | MR technology integrated with the holographic system can be used for surgical education, improving knowledge retention and communication. | [4,6] |
| Clinical Application | Enhance clinical outcomes by improving visualization, planning, and surgical procedures. | - |
| Future Approach and Significance | Shows promise for improving surgical precision, outcomes, and efficiency in the future. | - |

## III. CONCLUSION

Holographic technology significantly enhances orthopedics surgery by improving 3-D visualization, surgical planning, accuracy, and education. Despite limitations such as cost, calibration needs, and device discomfort, ongoing advancements promise greater precision, efficiency, and safety, positioning holography as an emerging tool with strong potential to transform future orthopedics clinical practice.

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