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Mixed Reality in the Operating Room: An Initial Use in Frontal Sinus Setback in Gender-affirming Facial Surgery

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Summary: Demand for gender-affirming facial surgery is growing rapidly. Frontal sinus setback, one of the key procedures used in gender-affirming facial surgery, has a particularly high impact on gender perception. Mixed reality (MR) allows a user to view and virtually overlay three-dimensional imaging on the patient and interact with it in real time. We used the Medivis's SurgicalAR system in conjunction with the Microsoft HoloLens Lucille2 (Microsoft). Computed tomography imaging was uploaded to SurgicalAR, and a three-dimensional (3D) hologram was projected onto the display of the HoloLens. The hologram was registered and matched to the patient, allowing the surgeon to view bony anatomy and underlying structures in real time on the patient. The surgeon was able to outline the patient's frontal sinuses using the hologram as guidance. A 3D printed cutting guide was used for comparison. Negligible difference between the mixed reality-based outline and 3D-printed outline was seen. The process of loading the hologram and marking the frontal sinus outline lasted less than 10 minutes. The workflow and usage described here demonstrate significant promise for the use of mixed reality as imaging and surgical guidance technology in gender-affirming facial surgery. *(Plast Reconstr Surg Glob Open 2024; 12:e5896; doi: 10.1097/GOX.0000000000005896; Published online 11 June 2024.)*

INTRODUCTION

Gender-affirming facial surgery targets key facial features influencing gender perception, such as the hairline, jaw, and forehead, aiming to enhance the alignment of a patient's facial appearance and their gender. Because the top third of the face has been shown to be the most influential on gender perception, forehead contouring via frontal sinus setback has become one of the most common gender-affirming facial procedures performed today.[1] In this procedure, the anterior wall of the frontal sinus is removed, burred down, and replaced to give the forehead a more feminine appearance.

The high degree of anatomical variation of the frontal sinus necessitates precise measurement of the sinus boundaries. Virtual surgical planning and resulting three-dimensional (3D)-printed cutting guides have been used to improve efficiency, safety, and accuracy.[2–4] Virtual surgical planning allows the surgical team to think through and refine precise planning preoperatively and 3D-printed cutting guides help guide marking and osteotomies intraoperatively. The cutting guides, however, can only represent a single "slice" of the patient's anatomy and fail to capture the nuances of 3D information, including the contours of the sinus cavity's inner walls.[4]

Augmented reality (AR) is a nascent imaging technology that can be used intraoperatively to visualize deep structures in multiple planes, overlaying volumetric renderings of computed tomography (CT) scans on a patient during surgery and avoiding the dimensional limitations of cutting guides. Mixed reality (MR) further expands on

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the surgical potential of AR by not only superimposing digital information on the real world but also allowing the user to interact with and manipulate that information in real time. Few studies have examined the use of MR in plastic and reconstructive surgery, and examinations of its use identifying the frontal sinuses have been limited to cadaveric work.[5] To the best of the authors' knowledge, none have yet explored MR in gender-affirming surgery.

We present a first intraoperative use of fully interactive holographic MR in a plastic surgery operating room in the United States, in the setting of a gender-affirming frontal sinus setback procedure performed on a healthy adult patient. Using MR imaging alongside the 3D-printed cutting guide, we examined the feasibility and accuracy of intraoperative MR and established a novel workflow.

Takeaways

Question: Is mixed reality a viable system for intraoperative anatomical identification during frontal sinus setback?

Findings: Mixed reality showed initial promise by minimally increasing operative time; being highly accurate, as compared with a three-dimensional-printed cutting guide; and providing improved understanding of the contours of the frontal sinuses.

Meaning: Mixed reality demonstrates promise for improving intraoperative anatomical understanding and surgical decision-making, although evaluations of expanded use-cases are necessary.

INTRAOPERATIVE USAGE

Immediately after dissection of the frontal bone was completed, the lead surgeon was fitted with the Microsoft HoloLens2, an AR/MR headset with a translucent visor running Medivis' SurgicalAR software (Medivis, New York, N.Y.). The Medivis system consists of a mobile computer workstation that volumetrically renders Digital Imaging and Communications in Medicine (DICOM) data and transmits it directly to the headset. The CT our patient received during their standard preoperative workup was uploaded to the computer workstation and displayed through the HoloLens2, allowing the surgeon to visualize the CT anywhere in the room and manipulate it freely using hand gestures that did not violate the sterile field. [**See Video 1 (online),** which displays looking through the eyes of the lead surgeon, J.A.G. (border images are not seen on the head-mounted display) as he manipulates the hologram.] Everyone else in the operating room was able to view the rendering on the monitor of the MR system.

The surgeon then identified and digitally marked several predetermined anatomical locations on the CT using the HoloLens2, namely the supraorbital notches, nasion, and glabella. Next, patient anatomy was precisely matched to the CT by placing analogous virtual fiducials on the patient with a localizing wand, which dropped an optical code in the stereotactic space at its tip, in a process known as registration (Fig. 1). When the surgeon was satisfied with the placement of virtual and real-world fiducials, he snapped the MR overlay into place with the software's match feature. Positional accuracy was confirmed through visual inspection of CT overlay and palpation of anatomical structures.

Next, the cropping feature was used to lower the depth of the CT and isolate only the most relevant anterior anatomy, allowing the surgeon to visualize not only the lateral and superior/inferior borders of the frontal sinuses but their deep borders as well. [**See Video 2 (online),** which displays looking through the eyes of the lead surgeon, J.A.G. (border images are not seen on the head-mounted display) as he registers the hologram to the patient and examines the frontal sinuses.] Using the MR outline as a guide, the surgeon marked the ideal level for osteotomy on the frontal sinuses; the MR-guided outline was essentially indistinguishable from results of the 3D cutting guide (Fig. 2).

DISCUSSION

This novel application of MR technology in frontal sinus setback demonstrated a high degree of 3D imaging

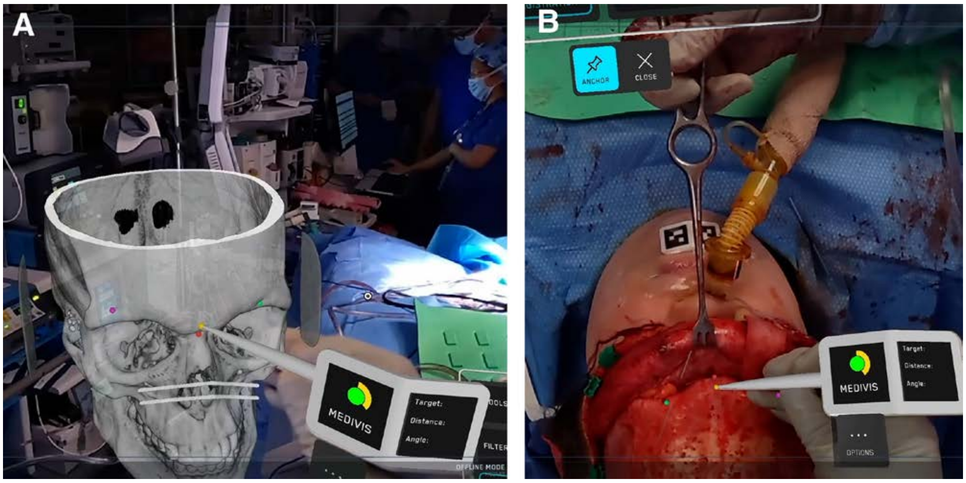

Fig. 1. Intraoperative registration of CT to the patient. A, Placing virtual fiducials on the holographic rendering of the patient's CT. B, Placing corresponding virtual fiducials on the patient themselves.

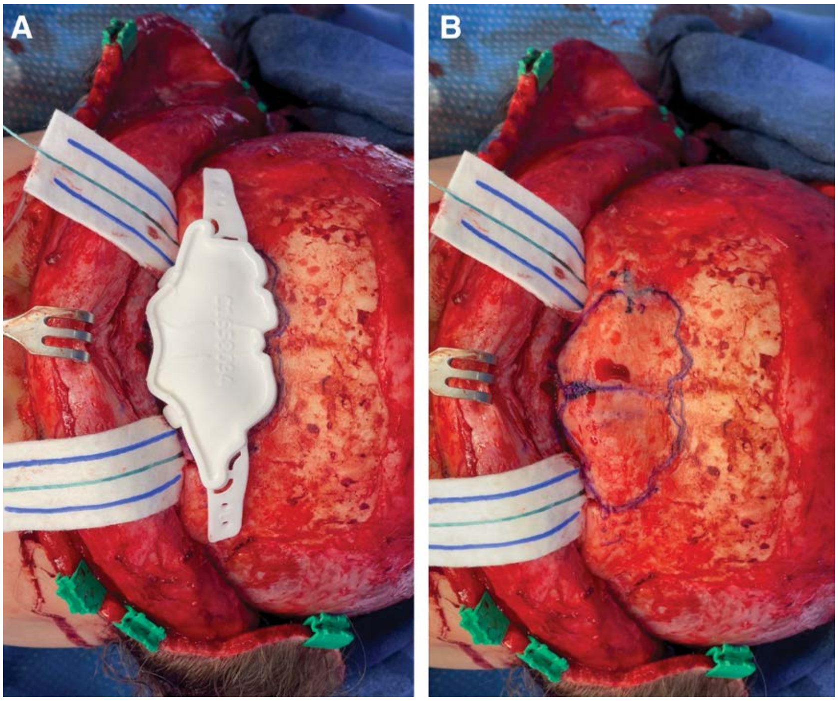

Fig. 2. Comparison of MR and 3D-printed cutting guide markings. A, Image of the 3D-printed cutting guide attached to the patient. B, Image of tracings of frontal sinuses from both the cutting guide and AR hologram.

accuracy with minimally increased operating time and preservation of surgical sterility, suggesting the viability of MR as an all-purpose and stand-alone image viewing platform.

The MR-guided osteotomy line was largely identical to that indicated by the prefabricated cutting guide, with a maximal discrepancy of 5 mm for less than 5% of the total tracing. The region of maximal discrepancy was primarily due to increased awareness of the contouring of the sinus walls, which led the lead surgeon to consider altering his osteotomy. In total, the registration and matching processes lasted only 3 minutes and 12 seconds, a significant portion of which included discussions between the technologist and the lead surgeon. Of that, fiducial placement on the holographic CT and on the patient's bony anatomy lasted 36 and 37 seconds, respectively, and matching the hologram to the patient took less than 1 second. Imaging cropping lasted 13 seconds, and marking of the osteotomy boundaries lasted 61 seconds. The system was intuitive and required no formal training outside of the manufacturer's included instructions.

This initial usage of MR demonstrated how 3D, interactive visualization of deep anatomical structures during surgery may improve intraoperative decision-making. We believe interactive MR will rapidly become an invaluable tool and possibly even replace 3D-printed cutting guides, although formal comparative analysis is necessary.

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DISCLOSURES

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