Extended reality is one of the leading cutting-edge technologies, which has not yet fully set foot into the field of ophthalmology. The use of extended reality technology especially in ophthalmic education and counseling will revolutionize the face of teaching and counseling on a whole new level. We have used this novel technology and have created a holographic museum of various anatomical structures such as the eyeball, cerebral venous system, cerebral arterial system, cranial nerves, and various parts of the brain in fine detail. These four-dimensional (4D) ophthalmic holograms created by us (patent pending) are cost-effectively constructed with TrueColor confocal images to serve as a new-age immersive 4D pedagogical and counseling tool for gameful learning and counseling, respectively. According to our knowledge, this concept has not been reported in the literature before.

**Key words:** 4D Ophthalmology, Cerebral Circulation, Counseling, Extended Reality, Mixed Reality, Pedagogy

Extended reality (XR) is an extension of augmented reality (AR), virtual reality (VR), and mixed reality (MR). To experience AR, a device that supports the AR module is required. To experience VR, a mobile phone that supports simple VR can be used, or commercial devices that are specifically made for VR purposes (e.g., Oculus Quest, and HTC VIVE Cosmos) can be used. There is only a fine line between AR and MR, which is comprehended better by a visual feeling than by theoretical understanding. Qualia of MR is achieved only through devices specially made for this purpose (e.g., Google Glass, HoloLens, and HoloLens 2).

The field of clinical and surgical ophthalmology is slowly but surely entering a three-dimensional (3D) era. Recently, Ramesh et al. reported the first paper on 3D eye holograms with TrueColor confocal images with AR for ophthalmic teaching. Although (3D) AR has become a substantial part of modern life in the last decade or so, (4D) mixed reality is still evolving. Hence, we have innovated and reported the use of 4D eye holograms (patent pending) with TrueColor confocal images with mixed reality, which has never been reported in the literature before.

**Innovation**

**The Inception of the Concept of XR/MR in Ophthalmology “Eye MG Holo”**

XR/MR is a futuristic concept that is still slowly evolving and emerging in the field of medicine and ophthalmology. During the COVID-19 pandemic, where interpersonal teaching is hindered and face-to-face counseling has many challenges, the impetus of XR/MR will pay rich dividends. Hence, we have innovated this concept “Eye MG Holo” to simplify 4D ophthalmic learning and counseling through holograms for powerful cognitive sessions.

**Prerequisites of “Eye MG Holo”**

For a successful XR experience with the holographic models created by us, the users would need a HoloLens 2 [Fig. 1].

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which is a novel MR device manufactured by Microsoft. It supports the hair-raising MR experience for the users. This is a head-mounted device, which the users have to wear overhead [Fig. 1] to use and view the 4D holograms. It works on the “Windows Holographic Operating System” running on a Qualcomm Snapdragon 850 processor.\(^8\)

What makes this device cutting-edge is the spatial recognition, eye-tracking, and hand tracking concepts. Spatial recognition senses the world around the user [Fig. 2]. Eye-tracking recognizes where the user is seeing. It also projects the holograms into the eyes of the user as light rays. The hand tracking concept [Fig. 2] helps the user to touch, move, rotate, and scale the holograms. It is a visual aura that should be experienced in an immersive manner as demonstrated in Video Clip 1.

4D Ophthalmic and Cerebral Holograms Provided in “Eye MG Holo”

The various 4D holograms [Video Clip 1] created by us are as follows:

1. Eyeball with real-time high-resolution TrueColor confocal fundus images [Fig. 3a and d, Video Clip 2]
2. Eyeball with real-time high-resolution angle structures [Fig. 3b and 3c, Video Clip 2]
3. Eyeball with real-time high-resolution TrueColor confocal fundus images of various pathologies in color, autofluorescence, and infrared images [Figs. 4 and 5, Video Clips 3 and 4]
4. Cerebral venous circulation with the cavernous sinus [Fig. 6 and Video Clip 5]
5. Cerebral arterial circulation with the circle of Willis [Fig. 7 and Video Clip 5]
6. Cerebrum, cerebellum, brainstem, cranial nerves with their nucleus and visual pathway anatomy [Fig. 8 and Video Clip 6]
7. Extraocular muscles [Fig. 9].

Referring to the standard anatomic and ophthalmic textbook images, we have constructed the 4D models in computer-aided design software such as Autodesk Maya and Blender.\(^9\) Maya LT software was the digital drawing tool that was used for modeling.\(^9\) Scaling was done for each part of all models using the CV Curve Tool (for length) and Extrude Thickness Option (for thickness).\(^9\)

USP of Holographic Models in “Eye MG Holo”

The 4D holograms were constructed by two anterior segment and two posterior segment ophthalmic surgeons, along with two skillful ophthalmic 4D generalists. The unanimated real-time TrueColor images acquired from the Eidon fundus capture device (iCare, Finland) were used for the construction of the 4D holograms. So, the 4D models are as reliable as the investigation’s output image; (i.e.,) in this case the investigation...
gadget being the fundus capture device. Similarly, complex structures such as the angles of the anterior chamber were constructed in 4D with photoreal visuals from real gonioscopy images. Objective judging for scientific reliability and proofreading of the holographic models were performed after 4D model construction by a team of four ophthalmologists. If any errors were found, corrections were made.

The fundus images used in “Eye MG Holo” were widefield, 110°, TrueColor confocal color fundus images along with autofluorescence and infrared images. With the installation of an ultra-widefield lens in the Eidon capture device, a field of up to 200° can be acquired, where the visualization of the fundus up to ora serrata is possible. With time, we intend to add more anatomical and pathological models as updates to the “Eye MG Holo.”

Setting Up the Framework for “Eye MG Holo”
We have set up the framework for “Eye MG Holo” by focusing on the method, where we can even share our experiences, with other HoloLens users in an efficient manner. They are as follows:
- Set up “OneDrive” account in Microsoft
- Turn on the HoloLens 2 device and install the “Microsoft Mesh App” from Microsoft Store [Fig. 10]
- Login with the Microsoft “OneDrive” account
- Now, the App automatically creates the required folders in the “OneDrive” account
- Copy the holographic models created in glb format, inside the “OneDrive” account at this particular location, “My files/Apps/Microsoft Mesh App/MyContent”.

By following the above steps, the holograms will be primed and ready to be launched for viewing in HoloLens 2.

Viewing the Holographic Models in HoloLens 2
The holographic models created by us can be viewed by following the instructions given below:
- Inside the Microsoft HoloLens 2 Device, open the “Microsoft Mesh App” by clicking on the holographic icon [Fig. 11]
- Inside the App’s menu, choose the “Content” option [Fig. 12a]
Select “OneDrive Cloud” icon [Fig. 12b]
Now, the different holographic models that have been added previously, can be viewed
Selection of any desired model from the various options can be done by the user
The selected model will get downloaded from “OneDrive Cloud” and then gets projected for viewing.

Economics, Pedagogical Transformation and Counseling with the 4D Holograms
All holographic models created by us are provided free of cost for HoloLens 2 users. The users will only need to own a HoloLens 2 to experience our TrueColor confocal anatomical and pathological images. The cost of the HoloLens 2 is approximately 3500 USD. Ophthalmic institutes and practitioners can invest in this cutting-edge technology to provide their neophyte ophthalmic residents and allied ophthalmic personnel with a real vision for understanding the concepts involved in patient care, and also revolutionize patient counseling in a way like never before.\cite{2,9,10} If the students/patients can see the 4D holographic models related to ophthalmology, right in front of their eyes in any size, from any angle of view they wish by holding, rotating, and scaling as they desire, it can change the way of teaching/counseling on a whole new level.

Conclusion
XR enhances the real world with immersive cinematic photoreal experiences by providing the holograms as a digital overlay over the real world. These holograms created by us can not only be visually perceived but can also be enhanced and controlled by touch. “Eye MG Holo” is a hi-tech solution for pedagogues to teach neophytes spatial anatomy and structures in vivid detail. Another highlight feature of the 4D ophthalmic holograms created by us is that they comprise TrueColor confocal images of the anterior segment and posterior segment structures with multimodal images of the retina, which has never been reported in the literature to date, in the field of ophthalmology. We believe that with time, this technology can advance from anatomy teaching to other widespread outpatient department procedures and various ophthalmic surgical simulation training.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest
There are no conflicts of interest.
Figure 8: (a–d) The image shows the holograms of the cerebrum, cerebellum, brainstem, cranial nerves with their nucleus and visual pathway anatomy from different views.

Figure 9: The image shows the holograms of the extraocular muscles of both eyes simultaneously as viewed through the HoloLens 2.

Figure 10: “Microsoft Mesh App” on Microsoft Store seen as a hologram, when viewed through HoloLens 2.

Figure 11: “Microsoft Mesh App” icon seen as a hologram, when viewed through HoloLens 2.

Figure 12: Image shows the holographic view of the (a) content options (red arrow) and (b) “OneDrive Cloud” icon (red arrow) after downloading the “Microsoft Mesh App” for viewing the different holograms in HoloLens 2.
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