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Araştırma Makalesi

Madencilik Makinelerinin Eğitiminde Artırılmış ve Karma Gerçekliğin Kullanımı

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Anahtar Sözcükler:
Madencilik Makineleri,
Artırılmış Gerçeklik,
Karma Gerçeklik,
AR Kitabı,
Hololens 2

Özet: Artırılmış ve karma gerçeklik, başta eğitim olmak fen bilimleri, sağlık ve mühendislik gibi birçok disiplinde kullanılmaktadır. Kendisine özgü donanım ve yazılımlarıyla sanal grafik tasarımların doğal çevre içinde görüntülenmesine ve etkileşimine dayanmaktadır. Bu çalışmada, açık ocak maden makinelerinin eğitiminde, artırılmış (AR) ve karma gerçeklik (MR) uygulamalarının etkisi incelenmektedir. AR Book olarak adlandırılan uygulamada, makine görselleri ve teknik bilgilerinin yer aldığı bir kitapçık oluşturulmuştur. Unity gerçek zamanlı geliştirme motorunda geliştirilen projede, Vuforia AR motorunda oluşturulan veri tabanı ve bunlarla eşleştirilen 3 boyutlu makine modelleri kullanılmıştır. Android cihazlar kullanılarak bu kitapçık üzerinde görüntü-hedefi tabanlı artırılmış gerçeklik uygulaması tatbik edilmiştir. Diğer uygulamada karma gerçeklik cihazı olan MS Hololens 2 için zemin-düzlem tabanlı bir uygulama geliştirilmiştir. El etkileşim özelliği ile gerçek çevrede konumlandırılan makineler sürükleme, döndürme ve ölçeklendirme işlemleriyle kontrol edilebilmekte, devasa boyutlara büyütülüp incelenebilmektedir. Eğitim alan grubun AR ve MR uygulamalarının geleneksel eğitimle birlikte kullanılması hususundaki değerlendirmelerine başvurulmuştur. Ayrıca mobil cihaz ve Hololens 2 arasında da kıyaslama yapmaları istenmiştir. Görüntüleme teknolojilerinin eğitime entegre edilmesi hususunda yüksek derecede olumlu sonuçlar alınmıştır.

Research Article

Utilization of Augmented and Mixed Reality in Training Mining Machines

Keywords:
Mining Machines,
Augmented Reality,
Mixed Reality,
AR Book,
Hololens 2

Abstract: Augmented reality (AR) and mixed reality (MR) are used in many disciplines, especially education, science, health, safety and engineering. It is based on the visualization and interaction of virtual graphic designs in the natural environment with its own hardware and software. In this study, the effect of augmented and mixed reality applications in the training of open-pit mining machines is examined. In the application called AR Book, a booklet containing machine visuals and technical information was created. In the project developed in the Unity real-time development engine, the database created in the Vuforia AR engine and 3D machine models matched with them were used. An image-target-based augmented reality application was implemented in this booklet using Android devices. In another application, a ground-plane-based application was developed for the mixed reality device MS Hololens 2. With the Hand Interactions feature, machines positioned in the natural environment can be controlled with drag, rotate and scale operations, enlarged to gigantic sizes and examined. The evaluations of the training group regarding the use of AR and MR applications together with traditional education were sought. They were also asked to make comparisons between the mobile device and Hololens 2. There have been highly positive results in integrating imaging technologies into education.

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1. INTRODUCTION

The participation of digital technologies in the processes has an important place within the concept of Education 4.0. In this context, many virtual, augmented and mixed reality applications are being developed chronologically. Virtual reality (VR) is a technology that transports the user into a completely artificial environment. Thanks to VR glasses, users can feel like they are in a completely different world. It is used in many areas from games to education, from the healthcare sector to architectural design. VR offers a completely virtual experience by completely disconnecting from the real world. Augmented Reality (AR) offers an enriched experience by adding digital elements to the real world. Many applications used on smartphones benefit from AR technology. For example, you can see how the furniture you choose will look in your home with the application of a furniture store. AR adds virtual layers to the real world based on it. Mixed Reality (MR) is a combination of VR and AR. In mixed reality, virtual objects can interact with the real world. In this way, users can hold virtual objects with their hands, interact with them and have an experience that coexists with the real world. MR is considered the most advanced form of VR and AR.

VR, AR and MR technologies have been frequently used in occupational safety training recently. Yang and Goh [1] aimed to establish a connection between the virtual and real world in occupational safety training using VR and MR technologies. By preparing 2 and 3 dimensional guidelines through these technologies, occupational safety training has been made more efficient. Rokooei et al. [2] investigated the contribution of VR technology to workers of different age groups in occupational safety training applied in construction works. Most of the workers stated through surveys that these technologies have positive effects on occupational safety. Gürer et al. [3] investigated the effects of VR technology on occupational safety in an underground coal mine by making a VR game. They observed its efficiency and effect by conducting surveys of 30 workers in the mining and gaming sectors. Workers in both business sectors stated that VR games can create high satisfaction levels that can raise awareness in occupational safety and support training. Eiris et al. [4] designed all 360-degree surfaces of construction sites with VR technology and provided occupational safety training to students and professionals in the sector with this technology. Employees and students in the sector stated that their three-dimensional perceptions and occupational safety training improved through VR technology. However, they emphasized that there were aspects that needed to be improved. It was stated that there were deficiencies in risk management. Chen et al. [5] investigated the effects of VR and AR technologies on fire training. In the studies conducted, they stated that VR technology created less anxiety and fear compared to AR technology. They emphasized that AR technology could create more realistic anxiety levels in the real environment. Hussain et al. [6] investigated whether VR and Artificial Intelligence (AI) could be used in occupational safety training of migrant workers from different countries to reduce construction costs and whether workers speaking different languages could be given quick and efficient occupational safety training. Their speech in different languages was integrated into the VR program via AI. It was stated that there was a 23% increase in knowledge among workers after the training. Alam et al. [7] used VR/AR technologies to make the work of workers in heavy maintenance jobs easier and to increase occupational safety in their work. They emphasized that technology could contribute to heavy maintenance jobs, but more modular and new technologies can contribute to making work easier. Sudiarno et al. [8] reviewed 60 VR studies and discussed the importance of VR studies in occupational safety training, the necessity of using these technologies in occupational safety lines, and the importance of the number of participants in the studies to be conducted. Yoo et al. [9] applied a survey to 248 construction workers after the application of VR occupational safety. According to the survey results, workers reported that they received occupational safety training with less anxiety because they felt safer compared to real working conditions and that their knowledge about occupational safety increased. Afzal and Shafig [10] investigated the effects of applications in different languages on occupational safety using VR technologies in a multilingual construction site. It has been stated that VR technology is effective in establishing common business goals and ensuring occupational safety before starting the applications, despite different languages being spoken on the construction site. Shringi et al. [11] organized training using VR technologies to increase the depth perception and environmental object awareness of crane operators. They stated that the training increased the awareness of crane operators, especially of surrounding objects (especially electrical cables), by 300%. Using IHA and VR-AR apps to scan and model accident sites provides the best work safety solutions [12-14].

VR, AR and MR technologies also have an impact on training in addition to occupational safety. Zhang et al. [15] tried to reduce environmental misconceptions in the production of coal required for the energy sector in China through VR/AR technologies. They reduced these misconceptions and false impressions by 23.4% by showing technological and green environment-supporting productions in the VR/AR system. Tarkkanen et al. [16] contributed to fire intervention training by making a VR/AR game for students to fight possible fires. Singh et al. [17] stated in their training studies that dragline excavations can be applied more efficiently by using unmanned aerial vehicles, AR and VR technologies.

VR/AR applications are used to model historical, touristic, and cultural heritage structures, among other structures, using 3D scanners [18-20].
AR technologies are generally used in real-world applications and training studies. In an underground drift in Canada, the blasting pattern is visualized in the blasting area through AR technology. In this way, easier holes will be created, and blasting efficiency will increase [21]. An AR study was conducted to show directions and provide gallery information during the progress of an underground mining operation [22]. It has been stated that maintenance and repair of devices used in underground mining operations can be done with AR applications [23]. The accuracy of drilling location determination in mining sites can be increased through AR technologies [24]. Demirkan and Duzgun [25] stated that it is possible to survive even in unlit environments in emergency situations by using AR headsets and spatial mapping algorithms in lighted or unlit conditions underground. Valencia Quiceno et al. [26] applied heavy vehicle operator training using AR technology and the Hololens 2 device. Operator training has been made more effective by creating user manuals, 3D objects, images and videos with AR. It has been stated that this application is very effective and promising in operator training.

Microsoft created the mixed-reality (MR) headset known as HoloLens. Users can interact with holographic images using HoloLens. Users can engage with these visuals and enjoy novel experiences since they behave like real-world actual items. HoloLens was created especially for use in fields including design, education and industry.
There are many studies on MR technologies, and the number of studies is increasing. Wu et al. [27] tried to detect and warn the distances to the environment, objects and hazards by attaching MR devices to workers in the construction sector. 96.1% hazard identification accuracy was achieved with this visual warning system. Liu et al. [28] investigated the benefits of MR technology in the mining sector using Hololens devices (MR). Real-time sound and images were used to achieve a realistic experience in the work environment. Li et al. [29] used the Hololens 2 device (MR), the Internet of Things (IoT) and Unity to observe and analyze the data of concrete pipes used underground using MR and IoT technologies. Altan et al. [30] contributed to education by designing serious games in the fields of health, bio garden and mining using VR and MR technologies. Mysiorek et al. [31] presented their training and experience in different application areas in the mining sector using VR/MR technologies and the devices of these technologies, Oculus 2 (VR) and Hololens (MR). It was emphasized that the contribution of these technologies in solving problems occurring in 3 dimensions cannot be ignored. Similarly, Onsel et al. [32] discussed the use of MR technologies (Hololens 2, MR Headset) to solve 3D problems in the mining sector. Demirkan et al. [33] aimed to detect the hazards that arise during rescue operations in underground mines by using thermal cameras, lidar, IMU and Hololens (MR) devices. It was observed that interventions were more reliable and effective with this wearable technology. Kaspar et al. [34] used MR technology in the formation of geological surfaces and images in the real world by using the Hololens device through 3D holographic images. Jing et al. [35] have made applications with MR technology using the Hololens headset, which provides a road map for escape from an underground mine in an emergency. It has been stated that it is effective in escape in emergency situations, but there are problems in road map calculations due to difficulties in Hololens scans in high-speed escapes.

In short, virtual, augmented, and mixed reality technologies are considered the technologies of the future. These technologies have the potential to revolutionize many sectors. In this study, the contribution of VR, AR and MR technologies in the grasp of different vehicles used in mining will be assessed through questionnaires. Students can only learn about these vehicles during internships or trips to mining sites. This study aims to investigate the contribution of digital technologies to support traditional education, shorten the learning time and increase the comprehension of the equipment better used in mining. In addition, the study aims to increase the effectiveness and efficiency of students in the training of open pit mining machinery.

2. MATERIALS AND METHOD

This research, considering the studies explained in the introduction section, aims to develop applications that will contribute to education in the field of mining and to test its usefulness for the education curriculum. For this purpose, open pit mining machines that students can usually see in photographs or movies were determined as the application subject. With the image target-based AR Book and ground plane-based Mixed Reality approach, it was possible to visualize the 3D models of the machines.

Unity and Vuforia were used as software in the study, and mobile phones and mixed reality smart glass Hololens 2 were used as hardware. The photographs to be used in the applications were determined by the standards of the Vuforia augmented reality engine. The database created was converted into a Unity package for the next stage. Three-dimensional machine models to be associated with each photograph must also be obtained from various sources or created in various package programs. The engine where all materials are brought together, and the final application is developed is Unity.

The work flowchart is shown in Figure 1, while the Unity project, including the machines matched to the image cards, is represented in Figure 2.

- Model preparation
- Vuforia Engine
- Unity Engine
- Smart phone deployment for AR Book
- Hololens deployment for mixed reality

Figure 1. Flowchart of the process.

For the first project, a machine booklet consisting of photos and their information was created. Figure 3 shows a preview of the book pages [36-46].

In the augmented reality application that can be used on mobile devices, 3D machine models were displayed holographically on the photos in the booklet [48-58]. In addition, AR hand interactions such as drag, rotation and scale (size enlargement and reduction) are allowed on the machines (Figure.4, 5 and 6)

2.1. AR Book Application

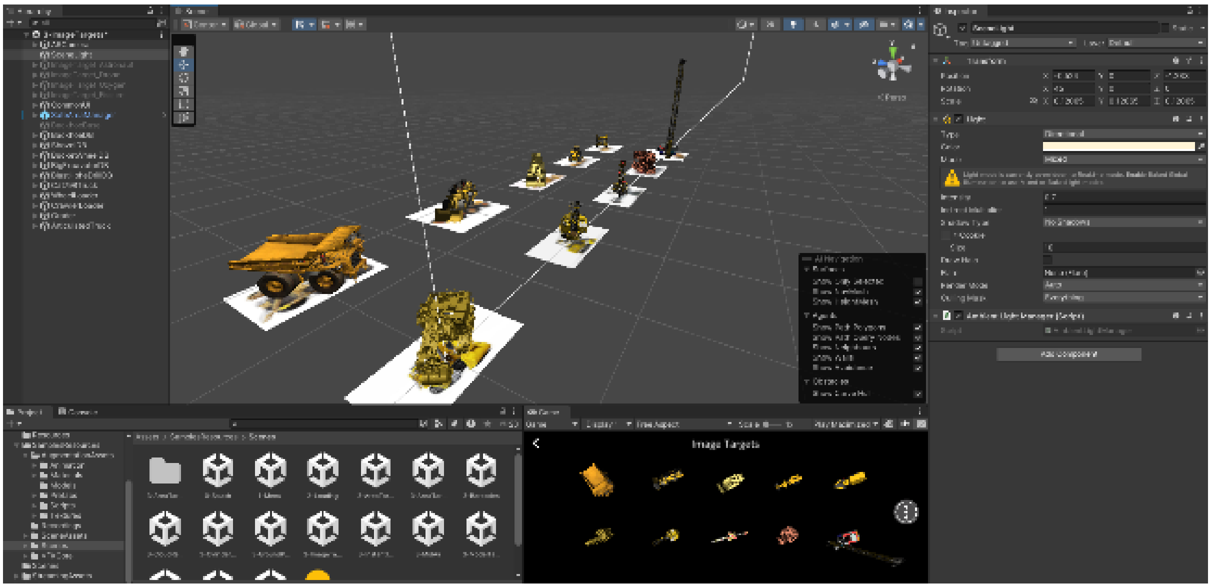

Figure 2. The machines used in the Unity project.

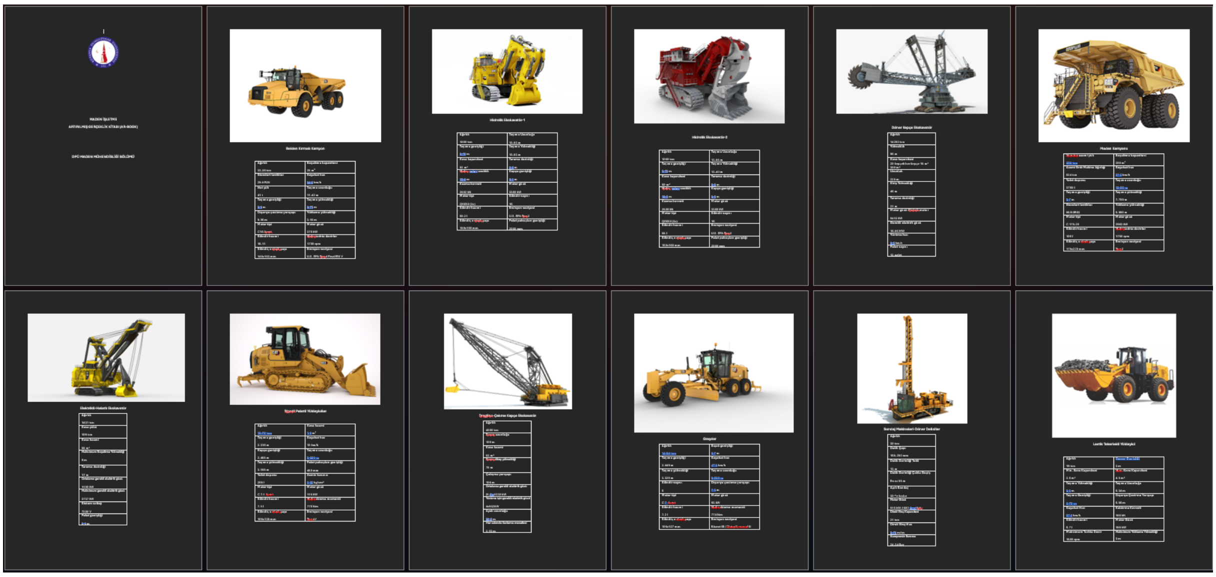

Figure 3. Preview of the AR Book pages.

In the augmented reality application that can be used on mobile devices, 3D machine models were displayed holographically on the photos in the booklet [47-57]. In addition, AR hand interactions such as drag, rotation and scale are allowed on the machines (Figure 4 and 6).

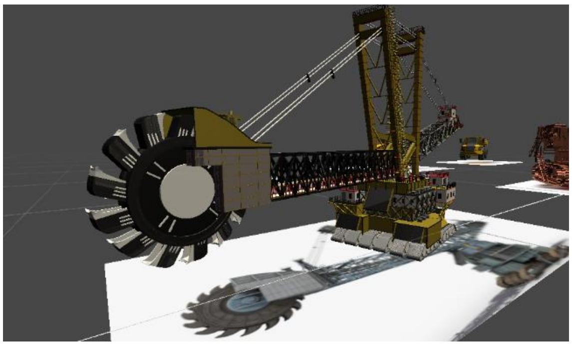

Figure 4. Bucket wheel excavator's image card [50].

Figure 5. Shovel excavator on the image card [51].

Figure 6. Wheel Loader on the image card [56].

2.2. Mixed Reality Application

The second application involves machine models created in 3D directly on the ground. This is a mixed reality application based on the approach called ground plane. There are manual controls (hand interactions) on the machines such as drag, scale and rotate operations. Each of the machines can be enlarged as much as desired, examined by walking around or entering inside. For example, applications on bucket wheel excavator (BWE) and dragline are shown in Figures 7 to 9.

Figure 7. Bucket wheel excavator's MR application.

Figure 8. Hand interaction on the BWE.

Figure 9. Dragging two giant machines by MR.

The application makes it possible for the machines to appear and be examined entirely as if they are in the same environment.

3. ASSESSMENT RESULTS

In order to determine the impact of the developed applications on their education, 22 students (8 female, 14 male) from different nationalities were asked for their opinions. The questions asked separately for AR Book and mixed reality and asked to rate them in the hundredth measurement system (1 to 100) are given in Table 1.

Additionally, a comparison table was given to the students for a holistic evaluation of the two applications to be graded from 1 to 100 (Table 2).

The averages of the grades given by the student group are represented in Figures 10 and 11.

Table 1. Template of the questions directed to the students for each application.

	QUESTION	POINTS (1-100)
1	I think knowledge is more memorable	88
2	It contributes positively to learning	87
3	Education becomes more enjoyable	90
4	It contributes to the quality of education	92
5	It increases the interest in the course	90
6	It would be beneficial if this application became more widespread	86

Table 2. Template of the holistic grades of the approaches and their comparison

AR Book mobile	Hololens-2 (Ground Plane)
85.91	92.45

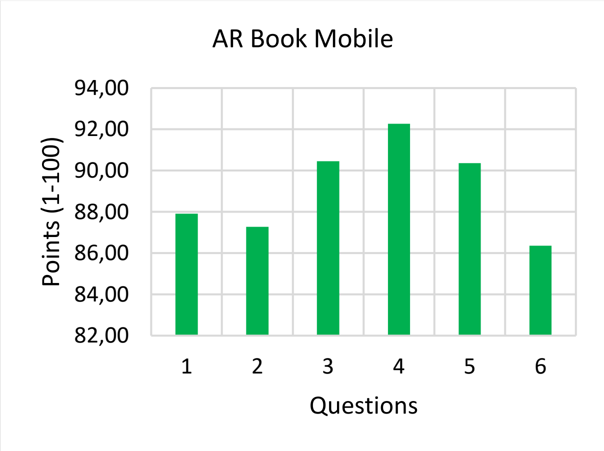

Figure 10. Assessments for AR Book-mobile phones

Here, considering the averages of the assessments in 100% measurement scale, students think that the knowledge will be more retainable (87.91%), it contributes positively to learning (87.27%), education becomes more enjoyable (90.45%), it contributes to the quality of education (92.27%), it increases interest in the course (90.36%), it would be beneficial if this application became more widespread (86.36%).

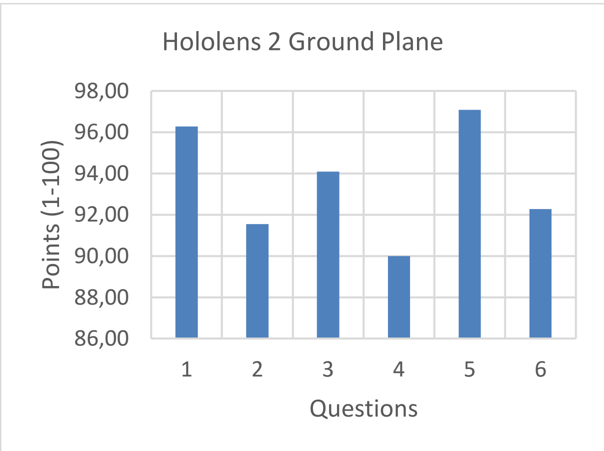

Figure 11. Assessments for MR-Hololens 2

In this assessment, students graded that knowledge will be more retainable (96.27%), it contributes positively to learning (91.55%), education becomes more enjoyable (94.09%), it contributes to the quality of education (90.0%), it increases interest in the course (97.09%), it would be beneficial if this application became more widespread (92.27%).

Another grading was for the comparison of the approaches in their contribution to traditional training (Figure 12).

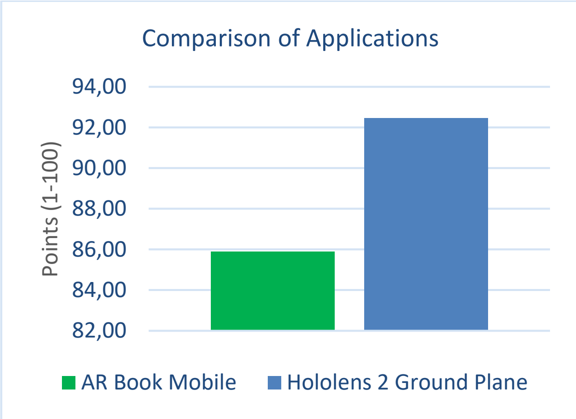

Figure 12. Comparison of the applications.

As can be clearly seen in the evaluation, the comparison of the contribution of AR Book Mobile and Hololens 2 mixed reality applications to education shows rates of 85.91% and 92.45%, respectively. According to the students' explanation, the reason why Hololens 2 is preferred over AR Book is that AR models are not squeezed into a small screen, interaction with models is possible, and machines can be examined in much more detail. A general common evaluation result is that education has been significantly improved by these new technologies.

4. DISCUSSION AND CONCLUSION

In this study, the effect of using augmented and mixed reality applications together with traditional education of open pit machines was investigated. For this purpose, image target and ground plane applications were developed using Unity real-time development, and Vuforia augmented reality engines. A database was created in Vuforia for the machines and used in the project in Unity. By matching the 3D models with the images in this database, the AR Book Android (APK) application was deployed to smartphones. Thus, the machines were displayed in the book with the interaction of mobile devices.

The other application was designed for the mixed reality device MS Hololens 2. In the application developed in the ground plane style, the machine models have dragging, rotating and dimensional scaling controls with hand interaction features. Thus, the trainees had the opportunity to have realistic positioning and viewing of the machines. The application was conducted by the group of trainees, and their opinions about their experiences were asked. The students were asked to evaluate the contribution of augmented reality, mixed reality and such technological approaches to education.

It is concluded with a very high level of conviction that in traditional education supported by AR and MR, knowledge becomes more memorable, contributes positively to learning, education becomes more enjoyable, the quality of education increases, interest in training increases and more use of such applications would be beneficial.

For the future, it is planned to conduct and develop new studies on the subheadings of effective and efficient education in the field of occupational safety and health, technical studies on university-industry cooperation on the basis of the existing work**.**

Ethical Considerations

Compliance with ethical guidelines

The authors declare that they have performed all procedures performed in studies involving human volunteers in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards.

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Conflict of interest

The authors declare that they have no conflict of interest.

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