Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

Virtual Reality in Veterinary Anatomy Teaching: A Review of Global Experiences and Its Relevance for Veterinary Education in Iraq

Omar Younis Altaey* **Ali Ahmed Hasan** **Saddam Abdalhussein Sadeq**
Department of Anatomy, College of Veterinary Medicine, University of Mosul, Mosul, Iraq

Abstract

Anatomy is the basic medical science in veterinary education, Traditionally, anatomy taught for many years through dissection and examination of cadavers. However, the advanced virtual technology present potential and promising teaching capabilities, therefore the current study intended to review the global experiences about application of virtual reality (VR) and augmented reality (AR) in veterinary anatomy, evaluate its benefits, and provide a recommendation to enhance anatomy teaching at the educational institutes in Iraq.An extensive search related to the using of VR and AR technologies in the anatomy and medical teaching was performed through researches online databases like (Google scholar, ScienceDirect, Web of Science, and PubMed) , then papers collected, analyzed, and explained. The majority of the research indicates that VR and AR technologies present beneficial learning experience, providing better information retention, more interactive learning, enabling remote accessibility, and reduce exposure time to formaldehyde gases. Furthermore, establishing VR and AR laboratories requires minimal equipment and spaces, cost-effective compared to the periodic need for the cadavers, preservatives, and dissecting tools. Future Iraqi laboratory should consider incorporating VR/AR units, implementing mandatory staff and students training, and encouraging the utilization of these technologies in medical sciences, particularly in the field of anatomy, as they offer valuable learning advantages

Keywords: Anatomy, Augmented reality, interactive learning, Veterinary, Virtual reality

Introduction

Anatomy considered the fundamental science for various medical fields. Through the study of anatomy, medical students gain knowledge about the structure of the animal body. Traditional anatomy teaching commonly involved cadaver dissection, long-time specimen preparation, and hands-on practical laboratory sessions. Sophisticated technologies have been developed to support the study of animal anatomy, such as three-dimensional (3D) printed models and 3D simulated graphics (1, 2). Virtual reality and augmented reality are two tools that have been developed to enable examination and manipulation of 3D graphics of natural or computer-generated models (3). Several available computer programs and mobile applications enable users to interact with 3D anatomical models by manipulating, magnifying, and even simulating dissection (4). Furthermore, these models have been developed and tested in multiple studies and educational facilities, demonstrating generally satisfactory results among different students (5, 6, 7). Many studies found that VR is attractive to medical students, reduces the use of animals, minimizes the risk of formaldehyde exposure, encourages repeated learning experiences, and improves memory retention since students have a greater comprehension of graphical data instead of textual data (3, 8, 9, 10). The extensive requirements for the development of these technologies have been affected by the global COVID-19 pandemic. It has become necessary to restrict direct contact activities. These challenges have affected the learning process, especially in medical education (11, 12). Despite the technological advancement, veterinary anatomy teaching in Iraqi universities still relies on the traditional method of using cadavers in situ. It is an opportunity to replace or, at the very least, incorporate computer-simulated technologies to enhance the teaching process and provide an easily accessible platform for medical students to learn veterinary anatomy with interactive capabilities. The present paper will discuss the utilization of these virtual simulations, their effectiveness, and students' perception, as well as the challenges and future directions. The objectives of this review article are to examine the application of VR in veterinary anatomy education globally, evaluate it benefits, and provide a recommendation to enhance anatomy instruction at the educational institutes in Iraq through the integration of VR modules

Virtual Reality and Augmented Reality in Anatomy Education

Definition and History

The virtual reality technology refers to the use of computer software and hardware to provide an interactive experience of simulation that replicates the sensations of real-life objects and events. This technology has the ability to produce real life scenarios through the learning environment, include building of visualized 3-dimentional figures controlled with motion sensors, keyboards, haptic devices, and headsets. Users can easily interact with this digital simulation in a way that feels like the real world (13,14). The AR technology refers to the superimposition of computer-generated data onto real life objects, locations, and entities. This technology enhances the user's learning experience by integrating physical elements with virtual objects using head-mounted displays and wearable microcomputer

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

overlays screens. (15).VR technology was known first in the 1950s when Morton Heilig invented the Sensorama, it a multisensory simulator was developed, combining a pre-recorded color stereo movies with enhancements such as binaural sound, scents, wind, and vibration experiences (16). This approach was the initial steps towards the creation of a virtual reality systems. The utilizing of this technology was restricted by military pilots training and astronauts (16).VR and AR were introduced in medical teaching field three decades ago as it was used at first in 1990 to study the colon and digestive system during gastrointestinal endoscopy training using computer supported simulation prototype at Duke university, UK (17). VR also used few years later in development of medical doctors' skills in cardiovascular endoscopy training (17, 18). The use of VR in anatomy teaching back to the 1990s, synchronized with the release of visible human project, This application found by National Library of Medicine which create detailed 3D male and female figures for learning purpose (19). While the use of immersive headset VR in anatomy education started in 2000s when this technology became accessible and advanced (8). Veterinary anatomy teaching by VR technology was reported in 2003 by Soomro and Bakhtiar., 2017 (20). The application found to provide accurate information for learners to study canine skeletal system and anatomical landmarks in the body of animal. Many authors focus on the importance of VR technology and its role in veterinary teaching (21,22,23).Erolin *et al*., 2019 (22) found that VR can help students in memorizing and understanding animal body structures, making the learning process more efficient and enjoyable. Meanwhile, Malinowski.,2003 (21) reports that conducting a three-dimensional representation of anatomy is a reliable and effective in teaching. It is through the demonstration of cadaveric specimens or the use of alternate reality using smartphones, tablets, headsets, or any other form of digital media (21).

VR applications in anatomy teaching

Visualization toolkit (VTK)

VTK (https://vtk.org/) has been an open-source system, freely offering 3D computer models, image processing, and scientific visualization. It's created in 2000 by group of scientists. It enables customized applications development. This application act as a designing tool rather than an end-user software, VTK simplifies the creation of applications such as ParaView and 3D Slicer. It widely used as commercial software due to operating system independence. However, there are some limitations. VTK is founded an older version platform (24). The optimizations for many features cannot be fully realized, and interactive rendering methods do not experience major performance improvements (figure 1) (24).

3D Slicer

3D Slicer (https://www.slicer.org/) developed as a software designed for medical image visualization and analysis. It serves in the field of medical images building and 3D visualization, targeting physicians and researchers working in medical domains. However, this software has a limited potential due to its reliance on the VTK framework. 3D Slicer is highly regarded as an analytic tool, with an active community of developers (figure 2) (25).

ParaView

A powerful visualization program (https://www.paraview.org/) utilized across various scientific fields like engineering, medical analysis and astronomy. ParaView handles massive datasets reaching terabytes sizes and distributed computing for increased processing might. However, despite capability to visualize medical and biological data, ParaView's reliance on VTK limits state-of-the-art, and volume rendering since the underlying framework was not designed for such complex 3D modeling of intricate biological structures at fine-grained resolutions required for scientific investigation and new discovery (26).

Biosphera

Biosphera (https://biosphera3d.com/) is the best illustration and designing software since 2011 with a focus on creating tools that make anatomy teaching and learning easier. One of their tools is the "Horse Anatomy software", which provides users with a detailed and immersive three-dimensional model of a horse body. With this software users allowed for in depth examination of different layers and zoom levels. It also offers features, like highlighting structures with informative captions or removing them to reveal deeper structures (figure 3) (27).

EasyAnatomy (Llamazoo)

The EasyAnatomy (https://easy-anatomy.com) is a state of art tool that provides a visualization of anatomy and allows dissection. It has gained popularity among schools worldwide for its specialized focus, on anatomy and physiology education (27). One of its standout features is the atlas of dog anatomy. This comprehensive resource includes representations of organs, vascular systems and muscular skeletal structures all derived from real dog data to ensure anatomical accuracy (28). Users can explore the details by peeling off layers of structures with each structure being fully annotated (27,28) (Figure 4,5).

Science in 3D

Sciencein3D (https://www.sciencein3d.com/) presents a program that extensively explores equine abdominal anatomy, the veterinarian's diagnostic approach, and 3D animations illustrating 28 diseases of the gastrointestinal tract (27). This program emphasizes interactivity and self-assessment, making it suitable for both veterinary students and equine practitioners. Noteworthy features include highly realistic 3D animations, interactive models, and detailed images with a valuable resource for first-year veterinary students studying equine abdominal anatomy. The comprehensive content is also included in the

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

"Anatomy of the Equine Abdomen" program (figure 6)
(27).

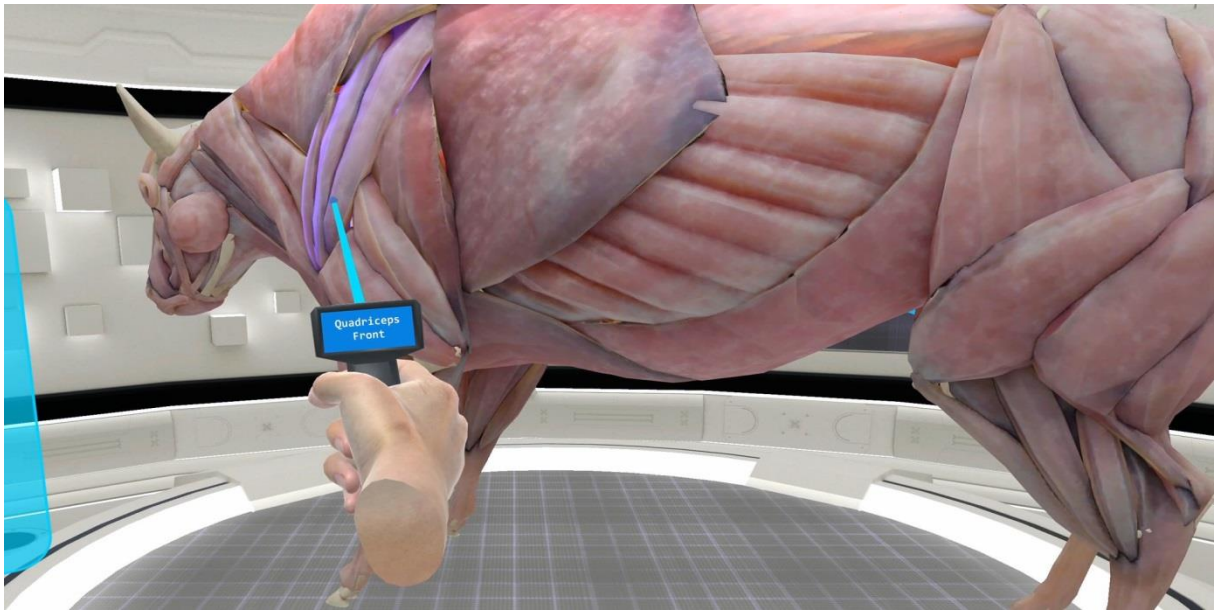

Figure 1: illustrate VR anatomy laboratory provided by ALTLAB™ one of VTK modern applications, allows users to learn animal anatomy by exploration of animal viscera with multi-layered digital same animal structures (https://www.altlabvr.com).

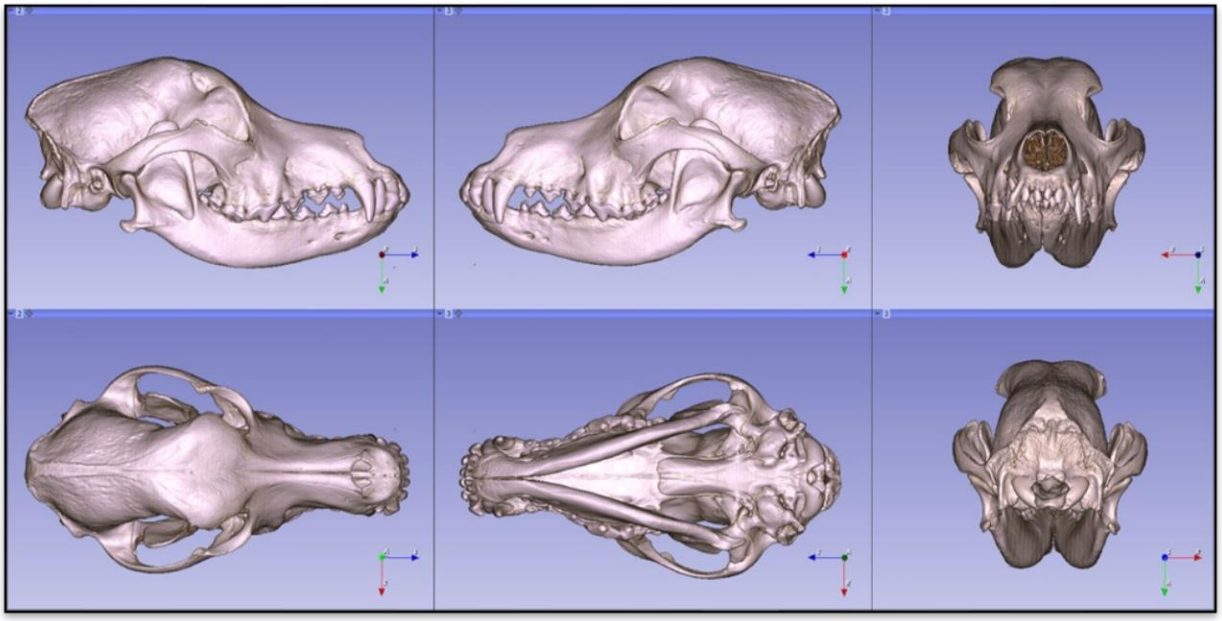

Figure 2: illustrating the 3D slicer software interface, showing the anatomical planes of skull in dog, used for teaching purpose the figure taken from website image gallery (https://www.slicer.org/).

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

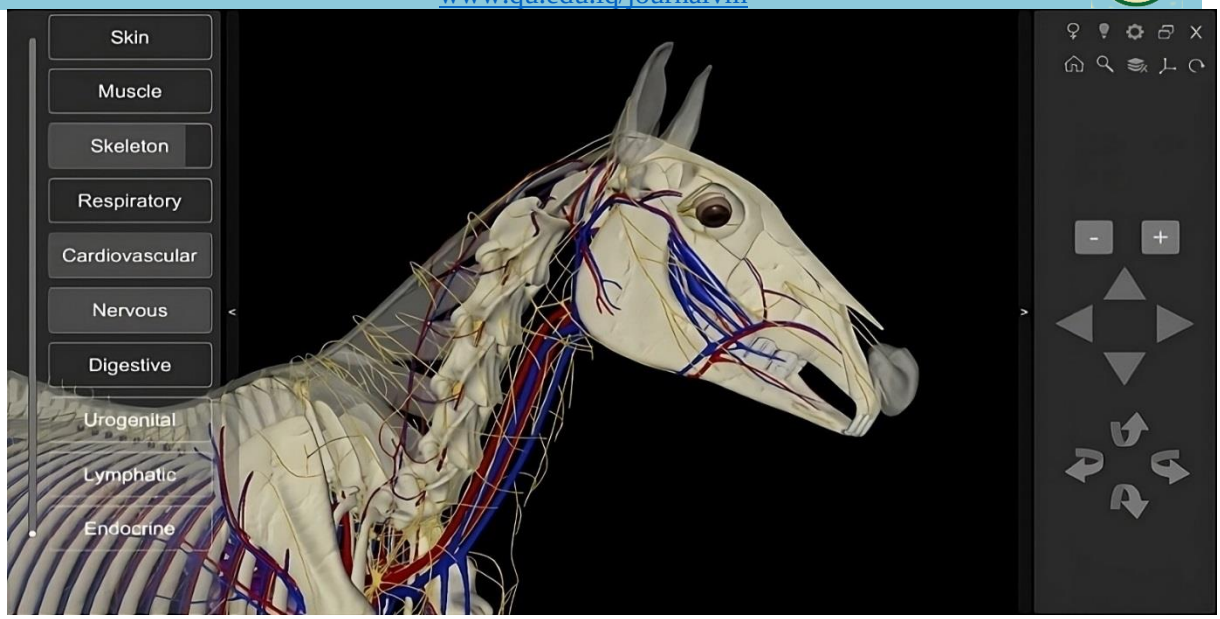

Figure 3: illustrating the Biodphera Horse software interface, showing the cardiovascular system imposition and neck arteries and veins location, the figure taken from website image gallery (https://biosphera3d.com/)

Figure 4: illustrate one of Llamazoo™ application called JetsonVR designed for teaching veterinary medicine students, to explore canine anatomy in a 3D, interactive environment (https://easy-anatomy.com) (28).

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

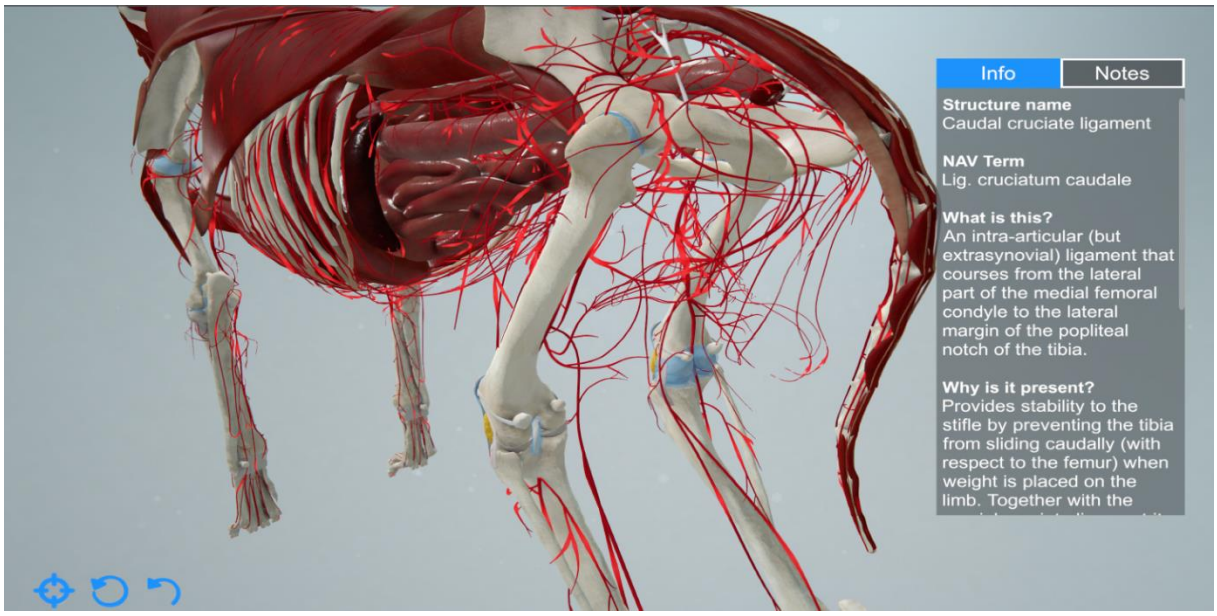

Figure 5: illustrate one of Llamazoo™ application called EasyAnatomy show 3D model of a dog's skeleton with a focus on the cranial cruciate ligament (https://easy-anatomy.com) (28).

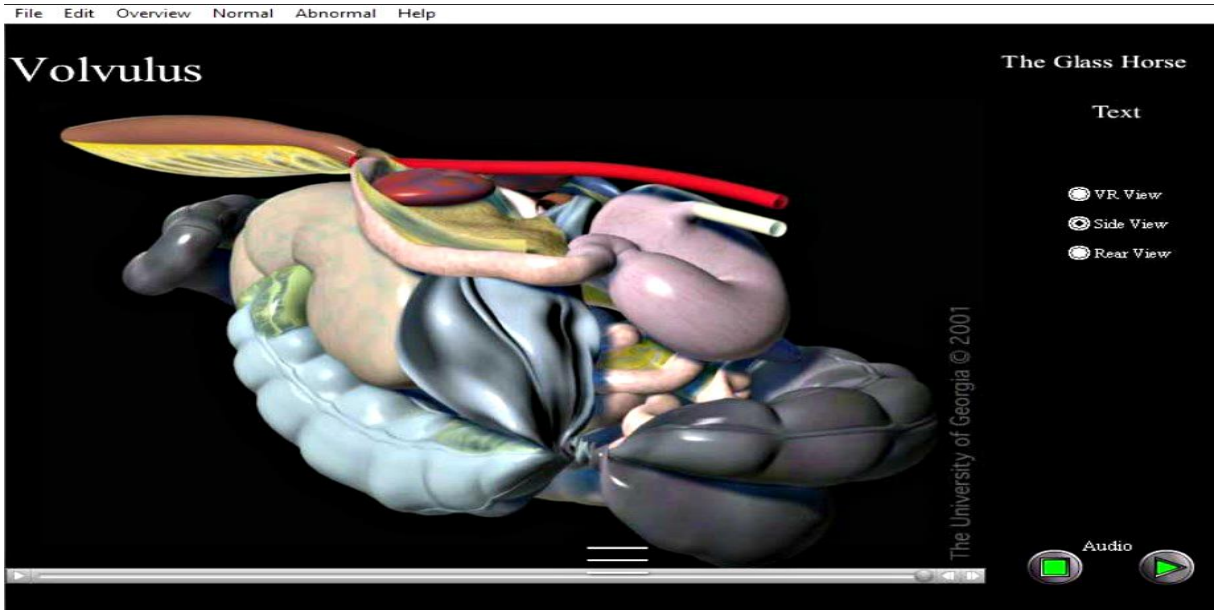

Figure 6: illustrating science in 3D software interface, the figure showing the volvulus clinical condition in horse with 3D and virtual modulation tools, integrated by instruction labels, the figure taken from gallery images (https://www.sciencein3d.com/)

(30) reported that the study experience of cardiac anatomy was more efficient with VR technology. Students exhibited improved dissection expertise and had more fun through the learning process.

Stepan *et al*.,2017 compared the utility of Oculus Rift VR with classic book learning in neuroanatomy among 1st and 2nd-year medical students. They found that the VR students group gained high scores and had an enjoyable experience compared to the classical learning

VR and AR in Anatomy Education

VR creates an alternative environment through computerized image design implemented over the local environment. It allows users to interact with virtual components using special sensors and headphones. De Faria *et al*.,2016 found that using 3-dimensional learning modules and stereoscopic instructions presents great potential for knowledge compared with traditional teaching methods (29). Maresky *et al*.,2019

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

alternative tool to keep education unceasing (13). The use of VR was the global adopted tool for teaching many medical practical lessons like anatomy Most authors found that future of the veterinary anatomy will transform to virtual mode such as 3D animations, simulator software, virtual dissections and E-museum servers (11,12,13). Virtual and augmented technology has been implemented across many medical and clinical fields. This includes learning about bone correction and bone surgery. Veterinary medicine students learn through clinical orthopedic rotations (36). They practice fractures fixation and radiographic interpretations. Researcher has revealed VR helps greatly with information and improves the clinical orthopedic setting (36), and suggest that VR can be used in many different ways because it's adaptability in both medical and clinical teaching situations. Augmented reality has also shown success for intravenous injection and venipuncture training of veterinary students, according to (37), this was performed using serial CT scans were taken of canine limbs displaying prominent veins. Using specialized 3D modeling software, the scans were converted into volumetric data. This allowed the radiological data to be reconstructed as realistic 3D stereographic models (37). Christ *et al*.,2018 explored utilizing an augmented reality mobile application focused on the canine head and nervous system. Researchers scanned a canine skull using MRI and CT technologies to generate highly accurate 3D anatomical models (38). These data files were then integrated into a user-friendly AR interface compatible with popular android devices. Students were able to view interact with the models overlaid directly onto physical skull specimens (38). In another study Kinnison *et al*., 2009 used haptic technology simulations for teaching bovine abdominal anatomy to veterinary students, The Haptic Cow simulator allows users to palpate and explore virtual representations of internal organs through (touch) feedback devices. Students were surveyed on their experience. Results revealed that students found the simulator useful for comprehending location of structures. Most also reported it enhanced their understanding of bovine anatomy beyond traditional methods alone. while some students requesting some additional time practicing (39).Based on the details provided, the authors found VR and AR technologies to be highly beneficial adjuncts for teaching anatomy. By allowing immersive, three-dimensional interactions with realistic virtual models. Students gained hands-on experience manipulating and dissecting structures in ways traditional lectures could not provide. Simulations gave opportunities to repeatedly practice procedures safely; students self-reported finding virtual methods more engaging and enjoyable than traditional methods alone. Incorporating virtual elements also enhanced education accessibility by remote learning and providing flexible options. (table 1).

group (31).In veterinary anatomy, the VR technique was used decades ago, and its importance has been described by many groups of authors. Dickson *et al*.,2022 (32) found that the use of virtual models is becoming increasingly important, with computer programs invented as supplements for traditional teaching methods. Cahyadi *et al*.,2022 focused on the importance of spatial ability in learning using future methodological advanced technology (33). The current study used control groups to compare students' spatial ability and general intelligence. Cahyadi et al.,2022 found that the use of VR improved veterinary anatomy study and provided a good distance learning opportunity during COVID-19 (33). Both authors found that using of 3D embedded anatomy simulators, provided essential information about animal anatomy and reducing ethical loss of animals. These studies showed significant financial improvement and highly interesting experience by students (32,33). Soomro and Bakhtiar.,2017 also focused on the importance of using virtual technology and spatial skills in anatomical education. This study used a three-dimensional method to reveal the canine skeletal system anatomy, and pointing out the landmarks on the skeletal bones (20). The students showed interest in continuing of the learning process after laboratories closed remotely, and obtained lectures on their personal computers (18). Singh and Banga.,2023 expressed the ability of students to use a manipulated level of displayed anatomy, the studied software was designed using Unreal Engine, CT scan, 3D slicer, and other 3D software (28). The experience showed that 1st-year students develop clinical skills by understanding canine body anatomy. Students voluntarily participated in using VR as part of their learning environment and the results showed that VR was an extremely effective tool in learning anatomical body features in dogs. Which encourage the development of cow and horse models later, and the application implemented by Oculus Rift CV1 and HTC Vive VR in their headset and controllers (28). Osorio-Echeverri *et al*., 2019 also report that VR 3D stereoscope video offer a great opportunity to help students to prepare for dissection, observations, measured by achievement of a post-dissection exams compared with teaching assistants' guide during dissection, students liked videos over the guided lectures (34). also found that the virtual feline anatomy program prepared by magnetic resonance scanning, imaging (MRI) scanning by computed tomography (CT) presents a supplemental tool for vet curriculum. By offering 3D visualizations through a well-designed interface, it enhances understanding of cat body structures beyond traditional teaching approaches (34).Authors found that Covid -19 pandemic accelerate the development of this technology around the world, Kapoor and Singh.,2022 reported that sudden lockdown of the academic institutes, and most of the teaching activities were suspended, and mentioned that all these challenges, provoked teachers to find

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

Table 1: Summary of Global Studies on the Use of VR and AR in Anatomy Education

No	Authors	Country	Date	Population students	Technology	Result
1-	De Faria *et al* (29)	Brazil	2016	84	VR (stereoscopic interaction)	Using virtual reality for teaching neuroanatomy was better than classic learning methods and students learn more and do better on tests with VR compared to traditional ways.
2-	Maresky *et al* (30)	Canada	2019	59	VR	Study experience of cardiac anatomy was more efficient with VR technology. Students exhibited improved dissection expertise and had more fun through the learning process.
3-	Stepan *et al* (31)	United States	2017	66	VR (Oculus Rift Headsets)	They found that the VR students group gained high scores and had an enjoyable experience compared to the classical learning group.
4-	Malinowski (20)	United States	2003	15	VR, 3D QuickTime video)	The students showed interest in continuing of the learning process after laboratories closed remotely, and obtained lectures on their modern personal computers
5-	DeBose (27)	United States	2020	65	3D software Biosphera, Sciencein3D, and Anatomage	The results showed that VR was an extremely effective tool in learning anatomical body features in dogs
6-	Lee *et al* (37)	South Korea	2013	40	AR	AR was a very effective training tool for medical students and could be developed for veterinary education future use
7-	Al-Khalili and Coppoc (34)	Canada	2014	104	VR (3D stereoscope video)	Observations measured by achievement on a post-dissection quiz and with the need for teacher assistants' guide during dissection and finding revealed that students liked 3D videos over the guided lectures
8-	Kinnison et al (39)	United Kingdom	2009	184	Virtual models (Haptic Cow)	the haptic simulator is a creative tool for teaching anatomy of bovine abdomen particularly to a large student’s number ina

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

						well organized manner without using cadavers
9-	Osorio-Echeverri et al (35)	Colombia	2019	Not mentioned	3D virtual Cat	this new virtual feline anatomy program presents a supplemental tool for vet curriculum. By offering 3D visualizations through a well-designed interface, it enhances understanding of cat body structures beyond traditional teaching approaches

Disadvantage of VR/AR technologies

Virtual reality (VR) and augmented reality (AR) have served as significant anatomy teaching tools. However, specialized trainers have documented that the abusive use of these technologies, resulting in negative consequences (40,41).These consequences, referred to cybersickness, act as an obstacle in the way of educational process. Cybersickness arises from sensory inconsistency caused, when visual perception contradicts the body's sense of balance, The brain struggles to accurately interpret body movements, leading to dizziness (41). Studies conducted by (40,15) have reported fatigue, disorientation, headaches, nausea, difficulty concentrating, and boredom Furthermore, It has reported eye problems such as blurred or double vision, eye soreness, and difficulty focusing associated with the use of VR (15). Cybersickness and most of the health problems associated with VR use, depend on multiple attributes, such as the field of view, frame frequencies, camera movement, and the intractability (41). Older users are more affected than novice users (41). Furthermore, first-time users experience more pronounced effects compared to users who have undergone pre-training. Additionally, people with existing eye diseases are more susceptible to cybersickness compared to individuals with healthy vision (40, 41).

Conclusion

According to encouraging recommendations of the previous studies regarding the use of virtual and augmented reality in anatomy teaching, It is imperative for medical laboratories to equip with these sophisticated technologies in Iraq, particularly within educational institutions such as colleges, teaching hospitals, and medical centers. Virtual reality has been established as a valuable learning tool for many years, with notable advancements occurring over the past five years as result of COVID-19 pandemic,Furthermore, establishing VR and AR laboratories requires minimal equipment, these laboratories do not require large spaces and cost-effective compared to the periodic need for cadavers, preservatives, and dissecting tools. Additionally, the use of VR and AR reduces the time of exposure to chemical preservatives and gases, making it as a healthier option. Moreover, globally, students have shown a greater interest and responsiveness towards VR and AR compared to traditional methods. Therefore, future Iraqi laboratory should consider incorporating VR/AR units, implementing mandatory training programs for staff and students, and encouraging the utilization of these technologies in medical basic and clinical sciences, particularly in the field of anatomy, as they offer valuable learning benefits.

Ethical Approval Statement

The review adhered to ethical standards for academic research by ensuring that all sources and studies referenced were appropriately cited and that the analysis was conducted with integrity and objectivity.

Acknowledgment

The authors thank the staff of the Anatomy Department, College of Veterinary Medicine, University of Mosul for their support and encouragement.

Conflict of interest

No conflict of interest disclosed by disclosed by authors.

References

1-Little WB, Artemiou E, Fuentealba C, Conan A, Sparks C. Veterinary students and faculty partner in developing a virtual three-dimensional (3D) interactive touch screen canine anatomy table. Med Sci Educ. 2019; 29:223-31. DOI:10.1007/s40670-018-00675-0

2-Hackmann CH, Dos Reis DD, de-Assis-Neto AC. Digital revolution in veterinary anatomy: confection of anatomical models of canine stomach by scanning and three-dimensional printing (3D). Int J Morphol. 2019 ;37(2): 486-90.DOI:10.4067/s0717-95022019000200486

3-Muntahir MI, Sukaridhoto S, Basuki DK, Budiarti RP, Al-Hafidz IA, Fajrianti ED, Hanifati K, Satrio NA, Syahry A. Implementation of immersive technology on medical education. In2022 International Electronics Symposium (IES)

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

2022.pp. 651-657. DOI:10.1109/IES55876.2022.9888379

4-Lewis TL, Burnett B, Tunstall RG, Abrahams PH. Complementing anatomy education using three-dimensional anatomy mobile software applications on tablet computers. Clin Anat. 2014 ;27(3):313-20. DOI: 10.1002/ca.22256

5-Allen LK, Bhattacharyya S, Wilson TD. Development of an interactive anatomical three-dimensional eye model. Anat Sci Educ. 2015 May;8(3):275-82. DOI: 10.1002/ase.1487

6-Codd AM, Choudhury B. Virtual reality anatomy: Is it comparable with traditional methods in the teaching of human forearm musculoskeletal anatomy?. Anat Sci Educ. 2011;4(3):119-25. DOI: 10.1002/ase.214

7-Nicholson DT, Chalk C, Funnell WR, Daniel SJ. Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model Med Educ. 2006;40(11):1081-7. DOI:10.1111/j.1365-2929.2006.02611.x

8-Chytas D, Johnson EO, Piagkou M, Mazarakis A, Babis GC, Chronopoulos E, Nikolaou VS, Lazaridis N, Natsis K. The role of augmented reality in anatomical education: An overview. Ann Anat. 2020; 229:151463. DOI:10.1016/j.aanat.2020.151463

9-Albrecht UV, von Jan U, Kuebler J, Zoeller C, Lacher M, Muensterer OJ, Ettinger M, Klintschar M, Hagemeier L. Google Glass for documentation of medical findings: evaluation in forensic medicine. J Med Int Res. 2014 ;16(2):e3225. DOI:10.2196/jmir.3225

10-Montes WB, Gómez JM. Implementar la realidad virtual en la enseñanza de anatomía una necesidad en la formación de profesionales de la salud. Morfolia. 2021;13(3):11-8.[available at]

11-Mehraeen E, Mehrtak M, SeyedAlinaghi S, Nazeri Z, Afsahi AM, Behnezhad F, Vahedi F, Barzegary A, Karimi A, Mehrabi N, Dadras O. Technology in the era of COVID-19: a systematic review of current evidence. Infect Disord Drug Targets. 2022;22(4):51-60.DOI:10.2174/1871526522666220324090245

12-Shamsabadi A, Pashaei Z, Karimi A, Mirzapour P, Qaderi K, Marhamati M, Barzegary A, Fakhfouri A, Mehraeen E, SeyedAlinaghi S, Dadras O. Retracted: Internet of things in the management of chronic diseases during the COVID-19 pandemic: A systematic review. Health Sci Rep. 2022;5(2): e557. DOI:10.1002/hsr2.557

13-Kapoor K, Singh A. Veterinary anatomy teaching from real to virtual reality: An unprecedented shift during COVID-19 in socially distant era. Anat Histol Embryol. 2022;51(2):163-9. DOI: 10.1111/ahe.12783

14-Bohil CJ, Alicea B, Biocca FA. Virtual reality in neuroscience research and therapy. Nat Rev Neurosci. 2011;12(12):752-62. DOI: 10.1038/nrn3122

15-Moro C, Štromberga Z, Raikos A, Stirling A. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. Anat Sci Educ. 2017;10(6):549-59. DOI:10.1002/ase.1696

16-Berryman DR. Augmented reality: a review. Medical reference services quarterly. 2012 ;31(2):212-8. DOI: 10.1080/02763869.2012.670604

17-Mandal S. Brief introduction of virtual reality & its challenges. International Journal of Scientific & Engineering Research. 2013;4(4):304-9. [available at]

18-Williams CB, Baillie J, Gillies DF, Borislow D, Cotton PB. Teaching gastrointestinal endoscopy by computer simulation: a prototype for colonoscopy and ERCP. Gastrointest Endosc. 1990 ;36(1):49-54. DOI: 10.1016/s0016-5107(90)70923-6

19-Breimer GE, Haji FA, Bodani V, Cunningham MS, Lopez-Rios AL, Okrainec A, Drake JM. Simulation-based education for endoscopic third ventriculostomy: a comparison between virtual and physical training models. Oper Neurosurg. 2017;13(1):89-95. DOI: 10.1227/NEU.0000000000001317

20-Soomro NI, Bakhtiar SM. Image-based modeling and precision medicine. InProgress and Challenges in Precision Medicine 2017. pp. 141-170. DOI: 10.1016/B978-0-12-809411-2.00008-8

21-Malinowski R. 3D K9: Using QuickTime VR to teach veterinary anatomy. Michigan State University; 2003: https://www.learntechlib.org/p/128409/

22-Erolin C, Reid L, McDougall S. Using virtual reality to complement and enhance anatomy education. J Vis Commun Med. 2019 ;42(3):93-101. DOI:10.1080/17453054.2019.1597626

23-Falah J, Khan S, Alfalah T, Alfalah SF, Chan W, Harrison DK, Charissis V. Virtual Reality medical training system for anatomy education. In2014 Science and information conference 2014.pp. 752-758. DOI:10.1109/SAI.2014.6918271

24-Schroeder WJ, Avila LS, Hoffman W. Visualizing with VTK: a tutorial.Computer graphics and applications. 2000;20(5):20-7.DOI:10.1109/38.865875

25-Fedorov A, Beichel R, Kalpathy-Cramer J, Finet J, Fillion-Robin JC, Pujol S, Bauer C, Jennings D, Fennessy F, Sonka M, Buatti J. 3D Slicer as an image computing platform for the Quantitative Imaging Network. Magn Reson Imaging. 2012;30(9): 1323-41.DOI: 10.1016/j.mri.2012.05.001

26-Lopes DS, Martins JA, Pires EB, Rodrigues LB, Las Casas EB, Faleiros RR. A geometric modeling pipeline for bone structures based on computed tomography data: a veterinary study. TAVARES, JMRS; NATAL JORGE, RM Computational vision

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

and medical image processing. Oxford. 2007:217-22.

27-DeBose K. Virtual Anatomy: expanding veterinary student learning. J. Med. Libr. Assoc. 2020;108(4):647. DOI:10.5195/jmla.2020.1057

28-Singh N, Banga HS. Librarian-Scientist (s) Collaboration in Harnessing the Potential of Augmented Reality (AR) and Virtual Reality (VR) for Veterinary and Animal Sciences Education and Training: A Success Story of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.2023 [available at]

29-De Faria JW, Teixeira MJ, Júnior LD, Otoch JP, Figueiredo EG. Virtual and stereoscopic anatomy: when virtual reality meets medical education. J. neurosurg. 2016;125(5):1105-11. DOI: 10.3171/2015.8.jns141563

30-Maresky HS, Oikonomou A, Ali I, Ditkofsky N, Pakkal M, Ballyk B. Virtual reality and cardiac anatomy: Exploring immersive three-dimensional cardiac imaging, a pilot study in undergraduate medical anatomy education. Clin.Anat. 2019;32(2):238-43.DOI: 10.1002/ca.23292

31-Stepan K, Zeiger J, Hanchuk S, Del Signore A, Shrivastava R, Govindaraj S, Iloreta A. Immersive virtual reality as a teaching tool for neuroanatomy. International forum of allergy & rhinology 2017;7(10):1006-013. DOI: 10.1002/alr.21986

32-Dickson J, Gardiner A, Rhind S. Veterinary anatomy education and spatial ability: where now and where next?. J. Vet Med Educ. 2022 ;49(3):297-305. DOI:10.3138/jvme.2020-0087

33-Cahyadi DD, Asfarian A, Novelina S, Setijanto H, Agungpriyono S. Virtual reality-based animal anatomy model: a new possible approach for veterinary education in Indonesia. ARSHI Veterinary Letters. 2022;6(1):11-2. DOI: 10.29244/avl.6.1.11-12

34-Al-Khalili SM, Coppoc GL. 2D and 3D stereoscopic videos used as pre-anatomy lab tools improve students' examination performance in a veterinary gross anatomy course. J. Vet. Med. Educ. 2014;41(1): 68-76.DOI: 10.3138/jvme.0613-082r

35-Osorio-Echeverri JS, Orrego-Metaute DA, Murillo-Escobar JP, Tamayo-Arango L. Three-dimensional cat virtual anatomy: development of an interactive virtual anatomical software. J Morphol Sci. 2019;36(02):105-14. DOI:10.1055/s-0039-1683964

36-McCaw K, West A, Duncan C, Frey D, Duerr F. Exploration of immersive virtual reality in teaching veterinary orthopedics. J Vet Med Educ. 2022;49(6):716-20.DOI: 10.3138/jvme-2021-0009

37-Lee S, Lee J, Lee A, Park N, Song S, Seo A, Lee H, Kim JI, Eom K. Augmented reality intravenous injection simulator-based 3D medical imaging for veterinary medicine. Vet J .2013;196(2):197-202.DOI: 10.1016/j.tvjl.2012.09.015

38-Christ R, Guevar J, Poyade M, Rea PM. Proof of concept of a workflow methodology for the creation of basic canine head anatomy veterinary education tool using augmented reality. PLoS One. 2018;13(4):e0195866. DOI:10.1371/journal.pone.0195866

39-Kinnison T, Forrest ND, Frean SP, Baillie S. Teaching bovine abdominal anatomy: Use of a haptic simulator. Anat Sci Educ. 2009;2(6): 280-5.DOI: 10.1002/ase.109

40-Birbara NS, Sammut C, Pather N. Virtual reality in anatomy: a pilot study evaluating different delivery modalities. Anat Sci Educ. 2020;13(4): 445-57.DOI: 10.1002/ase.1921

41-Oh H, Son W. Cybersickness and its severity arising from virtual reality content: A comprehensive study. Sensors. 2022;22(4): 1314.DOI: 10.3390/s22041314