Institute of Experimental Morphology, Pathology and Anthropology with Museum
Bulgarian Anatomical Society

Acta morphologica et anthropologica, 28 (3-4)
Sofia ● 2021

Repositioning Gross Anatomy Practical for Future Pandemics: A Paradigm Shift from Traditional to Effective Alternatives

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Background: The education sector around the world has been seriously affected by the pandemic including anatomy education which largely depends on cadaveric dissection. The COVID-19 pandemic has brought about new standards which cut across different spheres of life, including teaching and learning.

Results: Following the challenges experienced in conducting face-face teaching and practical; especially gross anatomy practical alongside online teaching during the COVID-19 school closures, it is imperative to adopt alternative models of conducting and teaching gross anatomy practical. These methods may not be entirely new; however, their use in some climes is almost non-existent while on a low scale in others. In this study, we explored the effective alternative approaches of teaching gross anatomy practical that may be used towards future pandemics.

Conclusions: These alternatives if adopted will bring much ease in switching between different modes in case of any future occurrences, such as the lockdowns experienced through the COVID-19 pandemic.

*Key words:*Anatomy education and practical; COVID-19; Cadaveric dissection; Pandemics; Gross anatomy

Introduction

The consequences of the COVID-19 outbreak on medical education entirely and anatomy educationcontinually unfold as the virus is still spreading [2, 32]. These effects were even more heightened due to the lack of a vaccine against the virus until recently. Even with the advent of vaccines, the complete elimination of the virus may still be a long way off especially in low and middle-income countries that lack production capacity or logistics infrastructure to rapidly inoculate their citizens. Therefore, continued closures of institutions may persist and practically oriented subjects like human anatomy that have been unable to undertake the traditional cadaveric practical teaching following the transition to online learning platforms may further be affected globally [29].

Even though there is a proposition that practical teaching may still be undertaken alongside online teaching [30], this is largely unrealistic in many climes that depend largely on cadaver dissection as the dominant means of gross anatomy practical teaching [9, 10, 28, 30, 34]. More so, teaching with human bodies has proven to be irreplaceable even in universities with the best technological resources. Thus, as long as doctors treat human beings, knowledge by contact with human beings will be essential.

Furthermore, with the frequent outbreaks of viral diseases in the last decades, it is pertinent to reposition anatomy education and particularly its practical aspects to be able to cope through periods of prolonged online learning. This paper explores alternative approaches of teaching gross anatomy practical that may be used side by side with the traditional cadaver dissection. These alternatives if adopted will bring much ease in switching between different modes in case of any future occurrence such as the lockdowns experienced during the COVID-19 pandemic.

Materials and Methods

A non-systematic search strategy was utilized in popular research repositories and databases, such as Google Scholar, Research Gate, Web of Science, Science Direct, and PubMed using selected keywords between January to May 2021. The keywords used to identify and extract articles relating and peculiar to the teaching of Anatomy include COVID-19, anatomy education and practical, cadaveric dissection; pandemic, gross anatomy, and anatomy teaching. This literature search yielded 70 publications and abstracts of the results were reviewed for relevance and inclusion in the study. A total of 50 articles highlighting different modalities for teaching anatomy practical met our quality and inclusion requirements and were identified, selected, and discussed. All articles were reviewed critically and included as appropriate to provide readers sufficient evidence for use of the highlighted methods.

Evolution of anatomy education

Human anatomy as a discipline has been regarded as being multifaceted, in which surface learning approach and rote learning of anatomical terms and catalog of structures has been espoused by most students [16]. The teaching of anatomy has been through a sequence of pedagogic lectures and laboratory practical concatenations which entails cadaveric dissection, observing prosected cadavers, and anatomical models [9,16]. The application of resources such as plastic models and computer-assisted simulator technologies in anatomy has been recommended as a way of dignity to seclusion in medical ethics [21].

The study of human anatomy is now a practical skill required by most medical practitioners, unlike its prior imaginative, humanist, and descriptive approach [12]. Learning anatomy using cadavers is a conventional technique for teaching anatomy.

Also, several kinds of research indicated that medical (anatomy) education will be ineffective without cadavers. Yet, certain researchers believe that a well-structured anatomy curriculum without cadavers may be equivalent or enhanced toone with cadavers for learning gross anatomy [48].

Cadaver dissection in anatomy education

Anatomy originates from the contraction of two Greek words, "Ana" (remove) and "Tomy" (cut). The record showed that the first dissection ofthe human cadaver was done by Herophilus and Erasistratus in the early 3rd century [44]. Over the years, anatomical studies have advanced and became recognized as a creative and spiritual study of life, travail, and death [35]. This gave rise to the "Anatomical Theatres" in Padua and Bologna in the year 1490 and 1637 respectively [35]. However, the quest for cadavers arose leading to shortages of cadavers. Bodies of executed convicts became the sole lawfully accessible cadavers that were available under the law [6].

What's more, the growth of medical schools and the concomitant surge in the request for cadavers at the beginning of the 19th century led to the prevalence of grave robbing despite its prohibition [49]. This surge in demand for cadavers necessitated legislation to make unclaimed bodies available to anatomists for dissection [49]. However, in recent years, voluntary donations of bodies have become a valid resource and standard for obtaining bodies for anatomy teaching and research in medical schools and universities globally.

Today, cadaver dissection is the fundamental approach in the teaching of anatomy which assists in learning the relations and macroscopic structures of anatomy formation [21]. Besides, anatomy laboratory particularly cadaver dissection is considered as the initial place for tutelage in the application of affective response among several others [43].

Consequences of COVID-19 pandemic on Gross Anatomy Practical

Towards the end of the year 2019, the novel coronavirus disease 2019 (COVID-19) emerged in China and by January 2020, quickly became an international public health emergency [22, 33]. Over 177 million individuals have contracted the virus and the death of over 3.8 million has been estimated in 221 countries/regions as of June 2021 [20]. The rapid transmission rate of the virus occasioned widespread lockdowns globally to interrupt its transmission [22, 33]. These have directly affected anatomy education as it largely depends on cadaveric dissection and the probability of being infected with the virus during dissection is high [22].

Additionally, the present COVID-19 pandemic has made accessibility to the human specimen for dissection difficult. Before this pandemic, the impetus for innovative teaching and learning approaches of anatomy as obtainable in various medical schools across the globe has been insufficient or inaccessible cadavers. This situation is even more acute due to this pandemic. Precisely one of the main problems of the pandemic was the reduction of voluntary donations and, therefore, lack of access and unavailability to those bodies.

Teaching and learning are now online, while the uses of 3D applications, simulators,virtual atlases, and several other digital resources have now become common place [22].Though technology has provided facilities for teaching and learning during the pandemic, if they are in a situation of lockdown, students will still not be able to access simulators, plastinated materials, and other digital resources that are in the same departments as the cadavers. For universities in low-income countries, most of the practical classes are on hold as the majority could not afford the resources for high-cost technology. In addition, the economic crisis posed by the pandemic and the failure of teachers to prepare teaching materials in normal times disrupted gross anatomy teaching especially in resource-limited settings where such high-tech platforms are not available, unaffordable and internet connection is poor [29].

Evaluation and validation of anatomical knowledge and examinations during the COVID-19 pandemic

Though novel pedagogical skills such as creative teaching, learning, and evaluation have been strongly emphasized for medical education in recent times, the process of memorization, visual memory, and auditory recall of anatomy knowledge (contents) by students can play a vital role in learning and understanding of anatomy [14, 24]. The process of memorization by students, and the online training sessions conducted for learners and educators by several medical schools have been so important during the pandemic, thus affirming the possibilities of recall memory via rote memorization.

As the teaching of anatomy and other medical-allied courses have resumed in the majority of medical schools and universities around the globe, it is essential to evaluate and validate the level and depth of anatomical knowledge derived by learners during the pandemic [37, 39]. The mode of assessment and examination of students' knowledge of the subject matter is also paramount to monitor learning outcomes and performances [39]. Though the universal experience with virtual examinations shows reasonable success with benefits to learners, alongside financial and logistical gain to the examiner, more improvements in virtual examination software and remote surveillance are required to overcome real cautions such as candidate verification, cheating inhibition, cybersecurity, and IT letdown [37].

Online examinations offer profits to both students and teachers in medical and anatomical examinations and may also save cost. Online examinations are expected to be progressively used in the post-COVID era, nevertheless, they cannot substitute the conventional assessment of students' anatomical knowledge [37].

Teaching gross anatomy practical beyond the COVID-19 pandemic era

The change in the world education sector due to the pandemic has also contributed to the teaching of anatomy. The quality of anatomy education can be enhanced by taking the opportunities of this situation, and the most efficient online anatomy education can be decided by learning from negative experiences during pandemics [47]. The new standards occasioned by the COVID-19 pandemic have cut across different spheres of life, including teaching and learning.

Following the challenges experienced in conducting practical; especially gross anatomy practical alongside online teaching during the COVID-19 school closures, it is imperative to adopt alternative models of conducting and teaching gross anatomy practical. These methods may not be entirely new; however, their use in some climes is almost non-existent while on a low scale in others [29]. Although, developing education methods on the online education system would make them suitable for use even after the pandemic [47].

Effective Alternative Methods to Traditional (Cadaveric) Teaching of Gross Anatomy Practical

Virtual dissection platforms

Virtual dissection is among some of the commonly employed teaching platforms following the COVID-19 pandemic and lockdown measures. Most often, disease outbreaks result in restricted access to cadavers especially in settings that depend largely on them. Still, virtual dissection programs via personal computers (PCs) offer its users easy and stress-free contact to cadaver dissection [29]. The advantages of virtual dissection relative to conventional cadaveric dissection cannot be overemphasized especially during disease outbreaks [29].

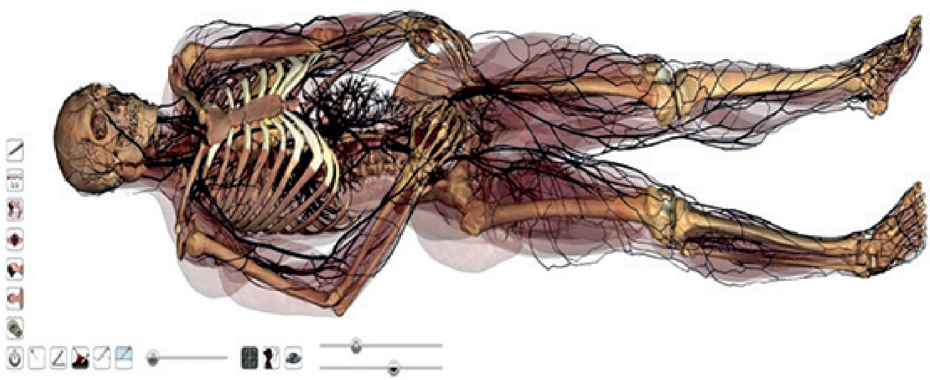

Fig. 1. Virtual dissection (Anatomage, Retrieved from https://www.anatomage.com/imagelibrary/)

Three-dimensional (3D) anatomy models

Three-dimensional (3D) anatomy models consist of both digital and non-digital resources. They include 3D computer, mobile- and web-based models, 3D plastic models amongst others. These models can be rotated or oriented into various positions to enhance learning. This way, the interrelation between separate anatomical structures in space and mental maneuverer can be appreciated. Gross anatomy and related knowledge of radiology are learned by some of the 3D digital anatomy models [4].

Nicholson et al. [27], reported that 3D anatomical ear models have a positive impact on students learning. A study on the use of 3D neuroanatomy tools conducted by Estevez et al. [13], revealed that 3D physical modeling is a prolific technique of learning the anatomy of the brain and assists students for visualization of 3D neuroanatomy.

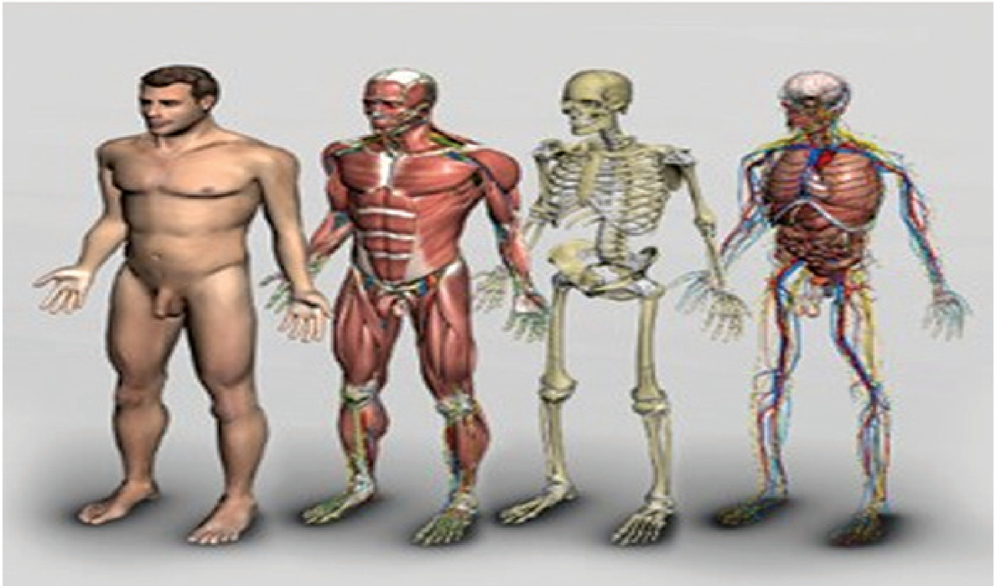

Fig. 2. 3-D Human Anatomy models (Norecopa, Retrieved from https://norecopa.no/norina/3d-human-anatomy)

Anatomy gaming

The idea of gamification in education is for learning rather than competition or entertainment. Generally, games are often designed and structured according to guiding rules for play which aims primarily to entertain; besides the competition inherent in them [38]. However, gamification in education aims to facilitate the achievement of curriculum goals using existing learning activities incorporated into games. The idea of gaming excludes engaging learners with a game within the classroom context [38]. It encompasses the use of game design features inconventionally non-game settings. The use of games is now increasingly employed as an attachment to customary teaching approaches in recent times [38].

In anatomy, gamification is employed in various forms comprising digital (web-based simulations, virtual and augmented reality) and non-digital forms (board and card games) [41]. Gamification allows participants the chance to relax and catch fun during learning [3]. This is essential and recommended for learning, as the art of teaching and sincere medical care demands energy and might be self-detrimental, thus causing burnout [3]. Gamification has been beneficial and a source of motivation to students and tutors as demonstrated by its ability to enhance study, retention, and knowledge application among students [3].

Worthy of note is that only the process can be gamified not the outcome. Since engagement rarely equates toreal learning, hence, gamification should not be performed in ways that interrupt the learning course [3]. Therefore, some behavioral changes such as motivation for self-learning must be adopted. Academic rigor should be sustained, despite students' need for a relaxed environment [3]. According to Mackenzie et al., gamification helps students develop mental models through playing the game to give accurate anatomical knowledge [23].

Plastination

Plastination was invented by Dr. Gunter VonHagens in the late 1970s. It entails the preservation of tissue of entire organs using polymers (resin and silicone) to simulate life-like specimens. This permits visualization of intractable anatomical concepts in a human body [35,11]. The use of plastinated prosections for teaching was first done in 2009 by the University of Warwick Medical School. This was followed by St George's and Nottingham Universities all in the United Kingdom [35].

Plastinated specimens pose no risk to human health since they are non-toxic, and can be moved freely from the laboratory to the classroom for learning. Congenital anomalies and pathology can also be displayed in plastinated specimens. Plastinated specimens could also be pinned easily for examination purposes and students' learning and 3D anatomical models can be developed from ultra-thin dissections of plastinated organs [7].

Three-Dimensional (3D) printing

The inception of rapid prototyping or additive manufacturing better known as 3D printing dates back to the late 1980s [50]. Nylon, metal, styrene, polyacetic acid, carbon fiber filament, acrylonitrile, and wood can be employed as materials to design three-dimensional printing digital models [18]. Based on the classification, the operation of 3D printing in medical education can be grouped into three treatments which are; modeling prototypes for surgical design, training, and education; natural tissue engineering, and designing implantable prosthetics [50].

3D printing technology can be employed to comprehend the anatomy of lesions and their related structures such as cerebral structures, vessels, and cranial nerves that are not well understood on radiographic two-dimensional images [50]. The manufacturing of various forms of anatomy specimen (bones, ligaments, tendons) of the same archetype as a real specimen with different strength materials can be performed via 3D printing [5].

Body painting

Body painting is an innovative approach in anatomy education that involves painting of the visceral organs (internal structures), muscles, vessels, bones, nerves on living human body surface which enhance better understanding of proportions and positions of anatomical structures [1, 14, 16, 19]. The practice of body painting by numerous tribes and cultures is an ancient form of art commonly used for ceremonial purposes, fashion, and entertainment [19]. This practice has been reinvented and applied to anatomical learning. Its earliest comprehensive practice for teaching can be dated to the year 1999 by Op Den Akker et al [31]. They developed a course that involved surface markings and tinting complete organs at the point of its prominence on the body performed by the learners [19, 26, 31].

Moreover, it was reported that this activity boosts the student's confidence for peer physical examination and assists in the acquisition of other clinical skills [1]. Body painting proffers the solution for the pertinence of gross anatomy in clinical practice through its knowledge of surface anatomy [14]. Among others, body painting has vastly assisted clinical skills teaching such as palpation, auscultation, and faster recollection of anatomical information especially surface markings of muscles and touchable bony landmarks.

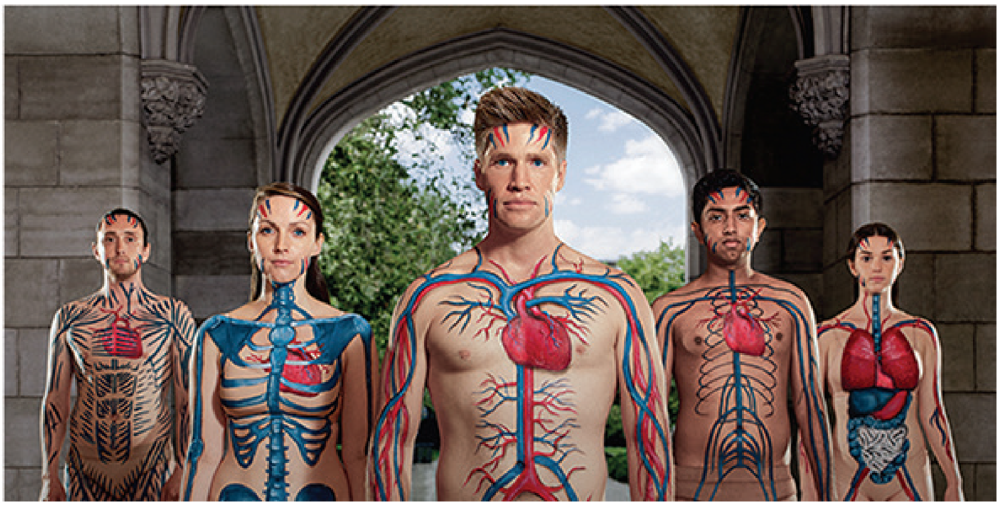

Fig. 3. Body painting (The University of Melbourne, Retrieved fromhttps://biomedicalsciences.unimelb.edu.au/departments/archived-departments/anatomy-and neuroscience/news-and-events/archive-news/grin-and-bare-it-for-science)

Photogrammetry

This entails the application of photographs of an object which integrates the use of photographs, videos, and computerized prototypes. At different angles, 2D photographs of an object are captured and later veneer via computer software to produce a 3D renovation [43]. Identical points between images captured at varying angles are recognized by the software, and it is also employed to glaze the images by harmonizing their common points [36].

Photogrammetry as a teaching tool is inexpensive, making use of common equipment like digital cameras, lighting tools, and some image processing software [36]. Application of photogrammetry has been applied in neuroanatomical morphometric studies where sequential sections of the brain have been made to study the structural network of cerebellar white matter [36]; examinations of tracheostomy in patients whom laryngectomies were performed, among others [36]. In anatomy education, photogrammetry could be used for the manufacturing of detailed, connected, and approachable digital 3D prosection models [36].

Medical imaging

The usage of imaging in teaching anatomy is necessitated by the need to elucidate radiology. Pathological organs and in vivo visualization of structures can be learned through imaging. However, radiological models cannot replace traditional dissection but will enhance better understanding [45]. Faculty and students in countries like the United Kingdom, Germany, United States of America have already adopted ultrasound imaging courses [45].

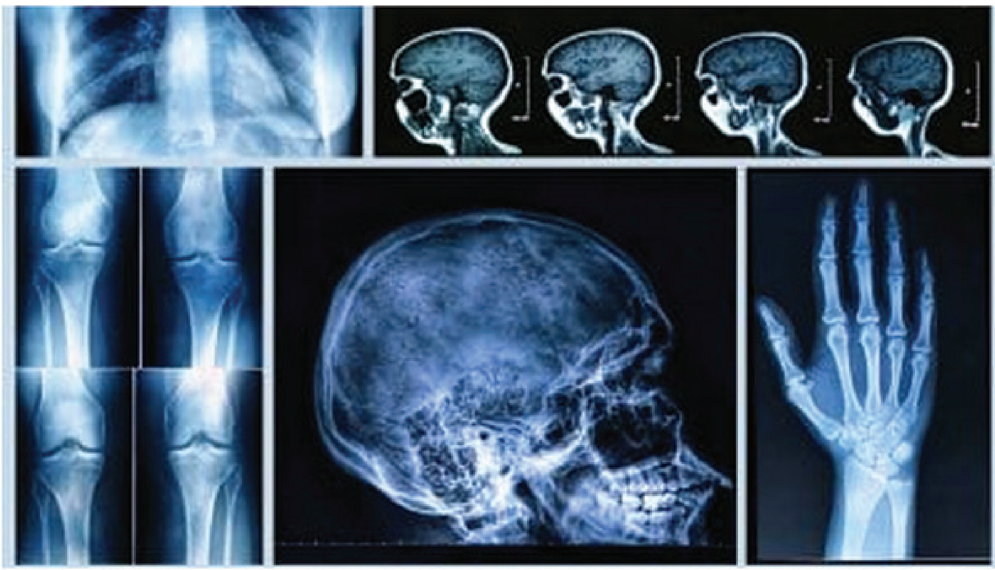

Fig. 4. Medical Imaging (Open MedScience, Retrieved from https://openmedscience.com/medical-imaging/)

Simulation

This is the act of juxtaposing the real and mimicking the natures of reality [21]. Medical simulators span from modest duplications of bodily structures for job-based learning to more advanced high patient simulators [46]. Anesthetists in the 20th century manufactured Resusci-Anne which is regarded as the first medical simulator [21]. Resusci Anne which also goes by numerous names (Rescue Anne, Resusci Annie, Resuscitation Annie, or CPR Doll) is commonly used in teaching cardiopulmonary resuscitation (CPR) [40]. Similarly, Laerdal SimMan is another moderate-accuracy patient simulator that is globally used [40]. This is a human simulator that can be used to perform heartbeat, carotid pulse, mouth moves, winking, measurement of blood pressure, duplication of human acts amongst others [21].

Medical simulation helps to harmonize the lacuna between the classroom and the clinical environment [40]. With the use of simulation, learners thrive in clinical skills and grow from being a novice to professional [40]. It also surges retentiveness and accuracy [40]. However, simulation should be simply to complement but not serve as a substitute for clinical education [21].

Spatial visualization

The ability to think and maneuver two- and three-dimensional objects mentally is referred to as spatial visualization. Research reveals students with developed spatial visualization abilities are more successful in science, technology, engineering, and mathematics (STEM) courses [42]. Spatial visualization can be applied in learning anatomical structures as it is best learned through interconnection to related structures. Anatomy atlases and texts permit only two-dimensional (2D) static anatomical representations and limited visualization of the functional anatomy of distinct dynamic areas [4]. Visual-spatial skills hold much promise for medical students, surgical trainees, and surgeons in the knowledge of anatomical structures [4].

Virtual and Augmented Reality

The constant demand for novel and efficient tools to teach anatomy has led to the rapid development of virtual (VR) and augmented reality (AR) technologies [8, 17]. The development and application of VR and AR devices, software, and application have made learning and studying of gross anatomy happen via hands-on immersive experiences. The learning of structural and gross anatomy through virtual and augmented reality isas effective and efficient as tablet-based (TB) applications [25]. The introduction of these novel modes of study has given rise to enhanced learning, engagement, and performances of students [8, 25].

The adoption and utilization of virtual and augmented reality have proven to be valuable and indispensable for teaching and learning anatomy as obtainable with other

Fig. 5. Virtual Reality (Bond University, Retrieved from https://bond.edu.au/news/48456/bond-science-students-get-lesson-%E2%80%98virtual-reality%E2%80%99-human-anatomy)

alternative modes [8,25]. More so, they encourage essential aids including enhanced immersion and engagement of learners. These consequences indicate boundless possibilities for the effective use of virtual and augmented reality as resources to complement lesson and curricular contents in anatomical education.

Conclusion

Conclusively, if these novel and innovative modalities are embraced and in place, the disruptions in gross anatomy practical teaching will not arise in the event of schools shutdown arising from future pandemics as realized during the COVID-19 outbreak. More so, it will allow for an easy transition in times of non-access to cadavers or dissection laboratories, thus ensuring that the learning of gross anatomy practical is sustained during such times.

Recommendation

Firstly, the application of emerging technology tools and integration of different modalities in teaching gross anatomy practical will hold much promise for students' learning. Secondly, the adoption of these innovative tools will enhance the assimilation and knowledge retention of medical students and learners in the anatomical learning process. Thus, the undue pressure posed on the sourcing and availability of cadavers will be drastically reduced, as alternative methods to teaching gross anatomy practical simultaneously with cadaveric dissection are now readily available.

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