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REVIEW ARTICLE

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Adapting to change: a systematic review of anatomy education methods during the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic has significantly altered the dynamics of medical education, particularly in the domain of anatomy teaching. This systematic review investigates the modifications implemented in anatomy education during the pandemic, emphasizing the shift from traditional pedagogical methods to online and virtual modalities. A comprehensive search across databases such as PubMed, Embase, Scopus, and Web of Science identified 10 studies that met the inclusion criteria. These studies collectively underscore the rapid transition to online platforms for conducting lectures, tutorials, and practical anatomy sessions. Despite challenges related to diminished hands-on experiences and concerns about student engagement, the integration of digital tools like virtual dissection software, 3D anatomical models, and Zoom-based flipped classroom sessions has demonstrated potential in maintaining the continuity of anatomy education. Notably, student feedback has highlighted both the benefits, such as flexible learning schedules, and the drawbacks, including internet connectivity issues and reduced practical exposure. This review highlights the need for further research to assess the long-term effectiveness of online teaching methodologies and their impact on students' clinical skills and professional development. Additionally, the perspectives of both students and faculty suggest that a blended approach combining online and face-to-face instruction could be viable path forward in post-pandemic anatomy education.

Keywords: COVID-19, anatomy education, online learning, virtual dissection, medical education adaptation

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Introduction

The COVID-19 pandemic has profoundly impacted various sectors worldwide, with education being one of the most significantly affected areas. The rapid spread of the virus and the consequent implementation of social distancing measures necessitated a swift transition from traditional face-to-face teaching to remote and online learning modalities [1]. This sudden shift posed considerable challenges for educators and students alike, particularly in fields that rely heavily on hands-on and experiential learning, such as medical education [2].

Anatomy, a cornerstone of medical education, traditionally relies on cadaveric dissection, prosection, and in-person lectures to impart a deep understanding of the human body [3]. However, the pandemic's restrictions have forced educators to explore alternative methods to ensure the continuity and effectiveness of anatomy teaching [4]. This has led to the adoption of various digital and online tools, including virtual dissection software, 3D anatomical models, Zoom-based flipped classroom sessions, and interactive platforms, to facilitate remote learning [5].

The shift to online anatomy education has raised questions about the effectiveness of these new teaching methods compared to traditional approaches. While some studies suggest that digital resources can complement and enhance anatomical understanding [5, 6], others highlight potential limitations, such as reduced hands-on experience and the challenges of fostering

student engagement in a virtual environment [7, 8]. Given the ongoing nature of the pandemic and the likelihood of enduring changes in educational practices, it is crucial to systematically review and evaluate the various anatomy education methods employed during this period.

Thus, the primary objective of this systematic review is to investigate the various methodologies employed for teaching and learning anatomy during the COVID-19 pandemic. The abrupt transition from traditional classroom settings to online platforms necessitates an evaluation of the impact on the efficacy of anatomy education. This review aims to identify the pedagogical practices implemented during this period, assess their effectiveness in comparison to conventional methods, and provide insights into the potential future trajectory of anatomy education in a post-pandemic world.

Methodology

Search strategy

The search strategy developed was to be very comprehensive and systematic. The search entailed looking at the main and classical databases holding a large amount of biomedical research; these included the databases of PubMed, Embase, Scopus, and Web of Science. The search strategy combined Medical Subject Headings (MeSH) and free-text keywords such as "anatomy education", "COVID-19", "online learning", "virtual teaching", and "medical education". Limiters in the search included articles that had been published since January 2020 and had to be published in the English language to reflect the impact of the COVID-19 pandemic on medical education and human anatomy. The review of available literature was conducted between 2 and 3 months.

Inclusion criteria

The inclusion criteria were specific to focus the review on studies that directly report on anatomy education amidst the COVID-19 pandemic. Studies were included if the intervention was implemented during COVID-19 or if the outcome was derived as a result of online delivery. The searches targeted educational interventions being done, methods of teaching adopted, or learning outcomes with relevance to anatomy in the context of pandemic education. The review will include both quantitative and qualitative research to have an all-inclusive, in-depth understanding of the subject under review.

Exclusion criteria

The exclusion criteria among all considered research included studies published before January 2020 and those not written in English. Other exclusions were reviews, commentaries, and editorials, focusing only on original research studies. Studies were also excluded if they described the interventions and outcomes as "educational" but provided inadequate details.

Study selection

The selection of the articles was performed independently by all authors. In total, 70 articles were pre-qualified for the study, and after removing duplicates. Twenty-nine full-text articles were assessed for eligibility, ultimately resulting in 10 studies that met the inclusion criteria. Initially, the title and abstract of those articles that may be of relevance to the topic were screened, and then the full text was reviewed for the selection of those articles that met the criteria. Disagreements among reviewers were discussed and resolved through consideration, or when needed, with the assistance of our lab supervisor Dr. Jacek Baj, to build consensus.

Manual search

In addition, the reference lists of the included studies were hand-searched to ensure no relevant studies were missed. This was particularly effective for identifying articles that may not have been captured in the database searches, adding to the comprehensiveness of the review.

Data extraction and synthesis

Data extraction was carried out carefully to ensure accuracy and comprehensiveness. From each selected study, information was extracted regarding the design, participant demographics, details of educational interventions, and outcomes. Key findings were identified, focusing on the challenges and opportunities of anatomy education during the pandemic. Specific attention was given to the impact of remote and online teaching methods compared to traditional approaches. Figure 1 illustrates the study selection process, providing a visual summary of the inclusion and exclusion steps. The results from the data extraction are compiled and presented in Tables 1–5, summarizing the study characteristics and key outcomes. This synthesis aims to provide a comprehensive overview of how anatomy

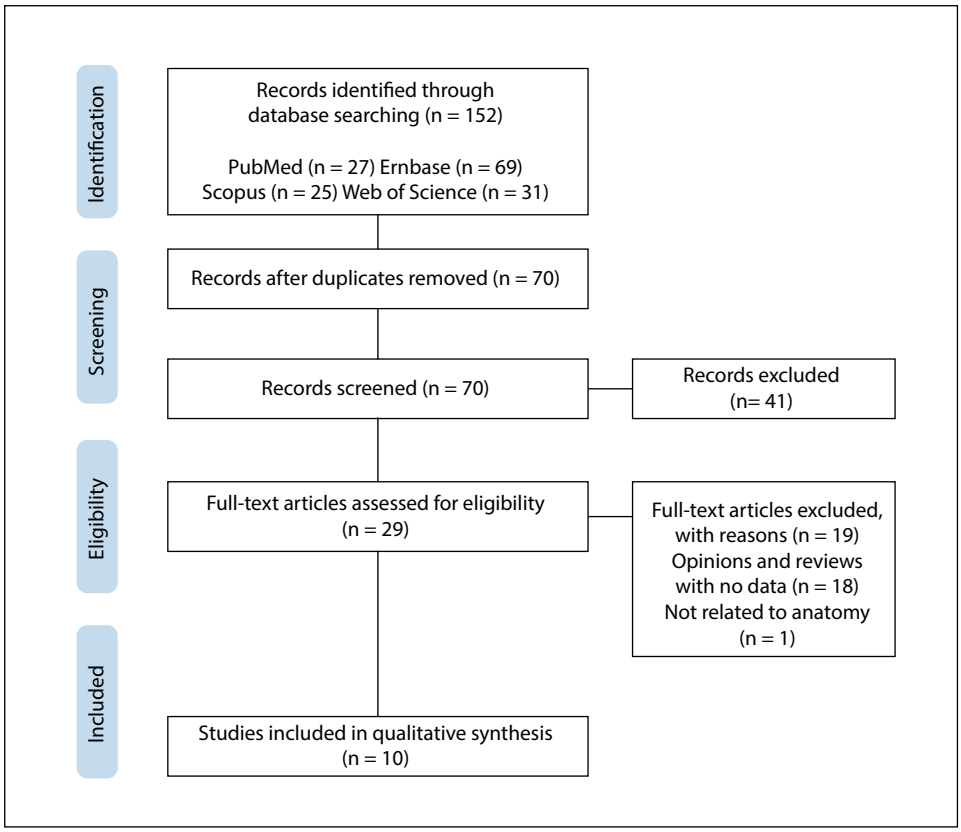

Figure 1. Flowchart presenting article search and selection according to the PRISMA guidelines

Table 1. Baseline characteristics of included studies

Author	Year	Medical Schools in Survey	No. of Responders	Subjects	Country
Cheng et al.	2021	77	77	Gross anatomy	China
Cuschieri et al.	2020	1	172	Anatomy	Malta
Harmon et al.	2021	Multiple	67	Anatomy	84% US & 16% Other
Longhurst et al.	2020	14	14	Anatomy	UK and Ireland
Pather et al.	2020	10	10	Anatomy	Australia and New Zealand
Roy et al.	2020	17	163	Gross anatomy, Neuroanatomy, Histology, Embryology	India (West Bengal)
Yoo et al.	2021	1	212	Anatomy	Korea
Srivastava et al.	2021	1	97	Neuroanatomy	India
Sadeesh et al.	2021	1	228	Gross anatomy and Histology	India
Roy et al.	2020	1	182	Anatomy	India

education has adapted during the COVID-19 pandemic. Insights gained from this review highlight areas that require further research and pedagogical development to enhance the effectiveness of anatomy education in a post-pandemic world.

Results

The systematic review identified a total of 152 studies. After removing duplicates, 70 papers were screened and 29 full-text articles were assessed for eligibility, as

Table 2. Mode of teaching anatomy before and during the pandemic

Author	Year	Mode of Teaching Anatomy Before Pandemic	Mode of Teaching Anatomy During Pandemic
Cheng et al.	2021	Theoretical online classes 74%, Practical online classes 33.8%	Theoretical synchronous live broadcasting 82.5%, Theoretical live broadcasting only 47.6%, Real-time interactive communication via voice note 65.1%, Real-time interactive communication via text 57.1%
Cuschieri et al.	2020	Face-to-face lectures, small group critical thinking sessions, clinical skills sessions, video dissection and hands-on cadaver and prosection dissection sessions	Pre-recorded lectures, Zoom sessions, group assignments, online resources including anatomy resources links, recorded cadaver and prosection sessions
Harmon et al.	2021	Cadaver teaching 76.2%, non-cadaver/plastic modality used in stand-alone course 4.7%, non-cadaver/plastic modality used in integrated course 10.5%, In-person lectures 76%	Cadaver teaching 34.0%, non-cadaver/plastic modality used in stand-alone course 51.5%, non-cadaver/plastic modality used in integrated course 43.5%, In-person lectures 8%, Synchronous delivery of lab content 46.7%, Asynchronous delivery of lab content 15.6%, Combination of two 18.8%, Gross anatomy software/ online resources 100%, Cameras and camera-related tools 22%
Longhurst et al.	2020	Face-to-face lectures, small group tutorials, practical sessions using cadaveric materials, and assessments involving practical exams	Recorded lectures 50%, Live tutorials 36%, Digitized cadaveric resources 38.6%, 3D virtual resources 7%, Both cadaveric and 3D virtual resources 43%
Pather et al.	2020	Face-to-face practical sessions using cadaveric materials, small group tutorials, and lectures	Synchronous delivery of lab content 20%, Asynchronous delivery of lab content 30%, Combination of two 50%, Gross anatomy software/online resources 100%, Recorded lectures 90%, Live tutorials 60%, Human donor program suspended 80%, Sessional teaching staff engagement 70%
Roy et al.	2020 (Perception Study)	Face-to-face theoretical and practical sessions	Zoom-based flipped classroom sessions, 92% preferred study material shared in advance, 79% found Zoom sessions helpful for doubt clearance, 53.36% struggled to keep up with daily classes, 61% reported internet connectivity issues
Roy et al.	2020 (Faculties' Perception)	Face-to-face theoretical and practical sessions	Google Classroom 37.4%, Zoom 31.2%, Google Meet 25.7%, Use of pre-recorded and live sessions, Sharing of PPTs during class 84.6%, Pre-recorded videos for practical sessions 46%
Yoo et al.	2021	Face-to-face lectures and practical sessions	Blended learning: Online lectures, pre-recorded laboratory dissection videos, 3D anatomy applications, and condensed offline cadaver dissection
Srivastava et al.	2021	Face-to-face lectures and practical sessions	Recorded lectures, Online live sessions, Real-time interactive sessions via text and video conferencing
Sadeesh et al.	2021	Face-to-face practical sessions using cadaveric materials	Online practical sessions, Recorded video lectures, Interactive quizzes

shown in Figure 1. Ultimately, 10 studies that met the inclusion criteria, encompassing a diverse range of educational interventions and outcomes related to anatomy education during the COVID-19 pandemic. These studies provide insights into the various methodologies employed to adapt anatomy teaching and learning in response to the challenges posed by the pandemic. The excluded articles consisted of 18 opinions and review articles that did not provide data and one article unrelated to anatomy education.

The included studies surveyed a diverse array of medical schools from various countries, including China, Malta, the United States, the United Kingdom, Ireland, Australia, New Zealand, India, and Korea, as seen in Table 1. The number of respondents in these studies varied, with some focusing on a single medical school, while others encompassed multiple institutions, as seen in Table 1. Tables 2–5 provides detailed information on the various modes of teaching anatomy

Table 3. Assessment during the pandemic

Author	Year	Assessment During Pandemic
Cheng et al.	2021	Online assessment 49.4%, 33.8% schools initiated online assessment during the pandemic
Cuschieri et al.	2020	Spotter examination (previously conducted within the dissection hall using cadaver prosections and histological slides, shifted to digital format using photos of cadavers and slides)
Harmon et al.	2021	Assessment in lab 20%, Computer 61%, Dissection and Prosection 14%, Imaging 51%
Longhurst et al.	2020	Practical assessment with online digital spotter examinations 21%, Canceled practical assessment 36%, Online MCQs assessment 36%
Pather et al.	2020	Inclined towards online assessments, Practical exams transitioned to online formats using images and videos
Roy et al.	2020 (Perception Study)	Online assessment through quizzes and assignments, home assignments preferred by 20.2%, recording of sessions preferred by 71%
Roy et al.	2020 (Faculties' Perception)	Online assessments through scan and email (88.9%), MCQ quizzes (57.7%), Online viva voce (26.3%)
Yoo et al.	2021	Scores in lecture exam: Class 2020: 82.35%, Class 2019: 76.36%; Scores in dissection lab exam: Class 2020: 68.44%, Class 2019: 63.74%; Total scores: Class 2020: 76.79%, Class 2019: 71.33%; MCQ test scores: Class 2020: 86.09%, Class 2019: 83.71%; Short answer scores: Class 2020: 80.14%, Class 2019: 71.88%
Srivastava et al.	2021	Online Viva voce: Satisfied with osteology images 61.4%, Radiology 80%, Embryology 82%, Surface marking 55%, Spotter online examination 59.6%, Gross anatomy online exam 33%
Sadeesh et al.	2021	Online spotter exam: Students comfortable with prosected specimens 59.6%, histology slides 52.2%. Viva voce: Osteology 61.4%, Radiology 80%, Embryology 82%, Surface marking 55%

before and during the pandemic, the assessment methods used, the outcomes or concerns associated with the new modes of teaching, the levels of anxiety experienced by students during the pandemic, and suggestions for reopening medical schools. The tables highlights the significant shifts towards online and hybrid modes of instruction, as well as the varied impacts these changes had on students and faculty.

A significant adaptation observed across the studies was the shift to online education during the COVID-19 pandemic. Cheng et al. (2021) reported that 82.5% of the surveyed institutions adopted theoretical synchronous live broadcasting, a substantial shift from pre-pandemic teaching methods [9]. Similarly, Harmon et al. (2021) observed a decrease in cadaver teaching from 76.2% to 34.0%.

The reduction in practical sessions, particularly cadaver dissection, emerged as a significant concern [10]. Longhurst et al. (2020) highlighted that 50% of the surveyed institutions reported a concern for the lack of practical/cadaveric exposure [11]. Additionally, Pather et al. (2020) noted that 80% of the institutions in their study had suspended their human donor programs, further indicating the challenges faced in maintaining practical anatomy education during the pandemic [12]. The studies also addressed the impact of online education on student engagement and learning outcomes.

Yoo et al. (2021) found that while online lectures were preferred by 79% of students, there were concerns regarding the clarity of lecture content and internet network problems, which could affect the effectiveness of online learning [13]. The study found that the scores in the lecture exam for the class of 2020 were higher (82.35%) compared to the class of 2019 (76.36%), whereas the scores in the dissection lab exam were lower for the class of 2020 (68.44%) compared to the class of 2019 (63.74%). Results are presented alongside other assessments, demonstrating the varied impact of online learning on different aspects of anatomy education as shown in Tables 3 and 4.

Cuschieri et al. (2020) conducted a survey-based study assessing the impact of the pandemic on anatomy education in Malta [14]. The authors found that students generally perceived remote teaching as equal to face-to-face instruction, with over 55% expressing satisfaction with the format. Pre-recorded sessions were particularly popular among students, with 63.4% indicating a preference for this mode of teaching. Additionally, Zoom sessions and group assignments were commonly used, and students had access to

Table 4. Outcomes/concerns with new modes of teaching and anxiety during the pandemic

Author	Year	Outcomes/Concerns with new modes of teaching	Anxiety during pandemic
Cheng et al.	2021	51.0% of teachers were satisfied with the effectiveness of online teaching, 36.2% preferred to continue online theoretical sessions post-pandemic, 24.8% teachers keen to return to traditional face-to-face anatomy education. Concerns included difficulty in grasping student progress and learning outcomes, unstable online teaching environments, and insufficient online teaching resources	Reported anxiety among students due to the lack of practical-based learning materials such as cadavers, dissections, or models, and the overall uncertainty and changes caused by the pandemic
Cuschieri et al.	2020	Satisfaction with online teaching 63.4%, Pre-recorded sessions liked the most 55.2%, Remote teaching considered equal to face-to-face 50%, Well-being affected 58.7%, Studying pattern affected 73.3%, Worried a great deal due to COVID impact on studies 46.51%, Worried about learning outcomes 41.9%, Worried about examinations 77.9%	Mean GAD-7 Score 9.58 (SD:5.2) (first year) 9.19 (SD: 5.30) (second year) GAD score less than 10 = 56.4%, Severe worry by students on their mental and emotional well-being OR: 20
Harmon et al.	2021	Increased use of digital resources, transition to image-based assessment, replacement of cadaver materials with photos and imaging	Reported increased anxiety and stress among students, with concerns about the adequacy of online learning for practical skills
Longhurst et al.	2020	Concern for time constraints 57.1%, Concern for lack of practical/cadaveric exposure 50%, Reduction in student engagement 36%	Reported increased levels of anxiety and stress due to changes in the learning environment and uncertainty about assessments
Pather et al.	2020	Concern for access to software and support for online teaching, technical failures, and network sustainability	High levels of stress and anxiety reported among students and staff due to rapid transition and uncertainty
Roy et al.	2020 (Perception Study)	Majority wanted to reduce the number of Zoom sessions per week, preference for three days a week	Network issues and inability to keep up with fast-paced sessions increased anxiety
Roy et al.	2020 (Faculties' Perception)	Concerns about maintaining competency, time management issues, need for strong internet connectivity	Perceived difficulty in maintaining student engagement and interaction online
Yoo et al.	2021	Students preferred online lectures due to increased self-study time, ability to study according to individual learning styles, and ability to repeatedly review lecture videos. Concerns included internet network problems (61.9%) and decreased student-teacher interaction.	Increased self-directed learning and enhanced concentration reported by students, but concerns about internet network problems affecting concentration
Srivastava et al.	2021	Advantageous modes: Student teacher interaction 81.44%, Tutor feedback 90.72%, Mentor meetings 81.44%, Stress relieving factors: Book reading 64.95%, Video calling 91.75%, Movies 84.54%, Exercise 87.63%, Gaming 42.27%, Following routine including online classes 65.98%, Peer interaction in online class 50.52%	GAD-7 during online classes: Minimal 43.3%, Mild 31.96%, Moderate 10.31%, Severe 14.43%, Small Group Discussions enjoyed by 84.53% students
Sadeesh et al.	2021	Challenges with online practical assessments included image resolution and difficulty in 3D orientation of soft parts. Over 60% preferred traditional assessment methods.	1.3% felt relaxed during online exam, 8.3% faced network issues

various online resources, including recorded cadaver and prosection sessions. However, the study also highlighted concerns related to students' well-being, with over 58.7% reporting that their studying patterns were affected, and 46.51% expressing significant worry about the impact of COVID-19 on their studies. Further, 77.9% of students were worried about examinations, and 41.9% were concerned about learning outcomes. The mean GAD-7 scores indicated moderate anxiety levels, with first-year students scoring 9.58 (SD: 5.2) and second-year students scoring 9.19 (SD: 5.30).

Sadeesh et al. (2021) reported mixed satisfaction levels with online assessments, indicating variability in the perceived effectiveness of online examination formats [15]. Satisfaction levels were rated based on students' feedback on various assessment components,

Table 5. Reopening medical school suggestions

Author	Year	Reopening medical school suggestions
Cheng et al.	2021	Willing to continue online theoretical sessions 36.2%, Willing to continue online practical sessions 0.6%
Cuschieri et al.	2020	Recorded lectures should remain post-COVID, lectures should be recorded for replay
Harmon et al.	2021	Recommendations for a hybrid model combining online and face-to-face learning to maximize benefits
Longhurst et al.	2020	Recommendations for a blend of online and in-person sessions post-pandemic to ensure practical skills are maintained
Pather et al.	2020	Recommendations for intensive practical sessions post-pandemic to ensure hands-on skills are developed
Roy et al.	2020 (Perception Study)	Suggested fewer sessions per week, improvement in internet connectivity, and use of recorded sessions for review
Roy et al.	2020 (Faculties' Perception)	Prefer continuation of some online methods for theoretical sessions while resuming physical practical sessions
Yoo et al.	2021	Recommendations for blended learning with increased online resources and periodic face-to-face sessions
Srivastava et al.	2021	Recommendations for flexible online and offline learning schedules to accommodate diverse learning preferences
Sadeesh et al.	2021	Suggested maintaining a digital resource bank and enhancing virtual teaching methods to supplement cadaveric teaching

including online viva voce and spotter exams. For instance, 59.6% of students felt comfortable with prosected specimens in online spotter exams, and 52.2% were satisfied with histology slides. Additionally, in online viva voce, 61.4% were satisfied with osteology images, 80% with radiology, 82% with embryology, and 55% with surface marking. **While 50.3% of students agreed that pointers and markings on the spotters were easy to identify, 33% felt comfortable discussing soft parts with images. Overall, 68.4% preferred traditional spotters, and 71.9% favored traditional gross anatomy discussions. Moreover, only 39.9% preferred conventional viva voce over online formats. Challenges included image resolution and 3D orientation of soft parts, with 8.3% facing network issues. Despite these issues, 1.3% felt relaxed during online exams compared to traditional methods.

Srivastava et al. (2021) focused on the experiences of medical students in India during the COVID-19 pandemic, with particular emphasis on the anxiety and stress factors associated with online learning [16]. The study found that interactive modes of online education, such as small group discussions and mentor meetings, were highly beneficial for students, with over 81% reporting satisfaction with these modes. The study indicated that 84.53% of students enjoyed small group discussions, and 80.41% felt that teacher-student interaction was adequate, although only 50.52% found peer interaction adequate. Additionally, there was a significant correlation between enjoyment of small group discussions and lower GAD-7 scores. Anxiety levels among students were assessed using the GAD-7 scale, showing that 43.30% had minimal, 31.96% mild, 10.31% moderate, and 14.43% severe anxiety. The study found significant changes in learning style preferences during the ERL period, with a notable increase in auditory and reading preferences and a decrease in visual and kinesthetic preferences. Moreover, feedback sessions and mentor meetings were considered helpful by 90.72% and 81.44% of students, respectively. Srivastava et al. (2021) reported that a majority of students found online classes and small group discussions to be advantageous modes of learning during the pandemic.

Despite the challenges, there is an indication of the potential for a more integrated use of technology in anatomy education. Roy et al. (2020) (Students' Perception Study) found that 92% of students preferred the current strategy of advanced sharing of study material before Zoom classes, with 79% finding the Zoom sessions helpful for doubt clearance [17]. However, 53.36% struggled to keep up with the progress of the classes in daily mode, and 61% reported internet connectivity

issues. The study suggested that post-COVID-19, there could be a continued use of online sessions and mini-group physical sessions to enhance learning.

Additionally, Roy et al. (2020) (Faculties' Perception Study) reported that 37.4% of faculties used Google Classroom, 31.2% used Zoom, and 25.7% used Google Meet for online teaching [18]. Furthermore, 84.6% shared PPTs during class, and 46% used pre-recorded videos for practical sessions. Only 5% of faculties felt that full competency could be achieved by students through online teaching alone. For assessments, 88.9% preferred sharing questions for students to write answers, scan, and email them, while 57% used MCQ quizzes. The faculties suggested fewer sessions per week, improvement in internet connectivity, and the use of recorded sessions for review.

Discussion

The advent of the COVID-19 pandemic has precipitated a paradigm shift in medical education, compelling a rapid transition from traditional, hands-on approaches to online and virtual teaching modalities, particularly in the realm of anatomy education. This shift, while ensuring educational continuity, has sparked debates about the adequacy of virtual platforms in providing the tactile and experiential learning that is quintessential to anatomy. The pandemic era has underscored the critical role of technology in medical education, not merely as a short-term measure, but as a potential catalyst for pedagogical innovation and enhancement. The reduction in practical sessions poses a significant challenge, necessitating creative solutions to simulate the hands-on experience that is fundamental to anatomy learning. This discussion will delve into the ramifications of these changes, exploring the impact on student engagement, the efficacy of online learning outcomes, and the prospects for a more technologically integrated approach in the future of anatomy education.

Shift to online education

The transition to online education, a strategy that was effective in certain regions during the 2003 SARS outbreak, has become a significant global adaptation in response to the COVID-19 pandemic [19, 20]. While the SARS outbreak primarily affected East Asia and led to localized shifts towards online education, the COVID-19 pandemic has necessitated a widespread and comprehensive adoption of remote learning across the globe [19, 20]. This shift has allowed students to acquire anatomical knowledge without the need for cadaver dissection, relying instead on online resources and textbooks [21]. As a result, many medical schools have begun to reconsider the necessity of cadaver dissection in their curricula [22]. The availability of anatomy education software for medical students is growing, but these resources can be costly.

Institutions should consider providing access to these tools during the pandemic and beyond, while software developers might offer trial access to ensure equity among institutions with varying financial capabilities [23]. Despite their utility, online resources may not always match the satisfaction and perceived educational value of cadaveric dissection sessions. The use of virtual tools can involve a steep learning curve for both teachers and students [24, 25]. The integration of new technology into the medical curriculum and its use to support learners throughout their educational experience, rather than merely serving as an alternative source, could lead to more efficient outcomes [25]. The shift to online education has also highlighted the importance of adapting teaching methods to suit the virtual environment. Educators have had to develop innovative approaches to engage students and ensure that learning objectives are met. Interactive platforms, virtual labs, and online assessments have become integral components of anatomy education during the pandemic [6, 26]. Furthermore, the move to online education has underscored the need for digital literacy among both students and educators [27]. The ability to navigate and utilize online resources effectively has become a crucial skill in the current educational landscape. The shift to online education during the COVID-19 pandemic has brought about significant changes in the way anatomy is taught and learned.

While there are challenges associated with this transition, it has also opened up new opportunities for innovation and inclusivity in medical education. The integration of new technology into the medical curriculum as well as its usage to aid learners throughout their learning experience might lead to an efficient outcome, as shown in Table 4.

Impact on practical sessions

The reduction in practical sessions due to COVID-19 poses challenges for students. The lack of physical interaction with teachers and peers and the limitations of remote instruction settings can impede the development of students as anatomists. Despite technological advancements enhancing online learning, traditional laboratory-based anatomy education,

primarily through cadaver dissection, remains highly effective [28]. The pandemic has also led to restricted access to essential learning materials, such as cadavers, models, skeletons, prosections, and pathological specimens [29]. Some researchers argue that the 21st-century medical curriculum has already limited students' exposure to anatomy, and the constraints imposed by the COVID-19 pandemic have further reduced contact time with practical learning materials [30]. While teaching anatomy without cadavers is feasible and has been adopted by some universities, the exclusion of hands-on materials like models and prosections can make learning more challenging [31].

The transition to online learning requires adaptation from both teachers and students and simply providing an online atlas may not suffice for students to fully appreciate the complexity of the human body [32]. The need for effective online resources that simulate the tactile and spatial aspects of anatomy has become more pronounced. Virtual dissection platforms and 3D models have emerged as valuable tools in this regard, offering an interactive and visually rich learning experience [33, 34]. Furthermore, the shift to online learning has highlighted the importance of fostering a sense of community and collaboration among students.

Peer interaction and group discussions, facilitated through online platforms, can help mitigate the sense of isolation and support a more engaging learning environment [35]. The impact of COVID-19 on practical sessions in anatomy education has underscored the need for innovative solutions to overcome the limitations of remote learning. As the situation evolves, it is essential for educators to continuously assess and refine their approaches to ensure that students receive a comprehensive and effective anatomical education.

Student engagement and learning outcomes

The transition to online education during the COVID-19 pandemic has raised concerns about student engagement and learning outcomes, especially in the context of anatomy education. Engaging students in a virtual environment presents unique challenges, as the tactile and hands-on nature of anatomy is difficult to replicate online [36, 37]. Studies have shown that active learning strategies, such as problem-based learning and interactive online modules, can enhance student engagement and improve learning outcomes in anatomy education [38, 39]. However, the lack of physical dissection and hands-on experience may impact the depth of understanding and the development of spatial awareness, which are crucial in anatomy [40, 41].

Furthermore, the shift to online learning has highlighted the importance of self-directed learning skills. Students who can effectively manage their time and resources tend to perform better in online anatomy courses [42, 43]. However, this also means that students who struggle with self-directed learning may find online anatomy education particularly challenging [44]. The assessment of learning outcomes in online anatomy education has also been a topic of discussion. Traditional assessment methods, such as practical exams and dissection assessments, are not feasible in a virtual setting. Alternative assessment methods, such as online quizzes, virtual spotter exams, and case-based assessments, have been employed, but their effectiveness in measuring deep anatomical understanding is still under investigation [45, 46].

While online education provides an opportunity to continue anatomy education during the pandemic, it also poses challenges in terms of student engagement and learning outcomes. Further research is needed to develop effective strategies for online anatomy education that can replicate the benefits of traditional hands-on learning.

Potential for future integration of technology

The evolution of anatomy education has been marked by significant changes, particularly in the current era, characterized by constraints such as limited time, reduced availability of cadaveric resources, swift technological advancements, and evolving requirements in medical education [47–48]. Furthermore, there has been a notable paradigm shift from traditional, didactic, passive, and teacher-centered approaches to contemporary, clinically based, active, and student-centered approaches [47]. This shift has sparked ongoing debates about the most effective methods for teaching anatomy, with the challenge of finding a balanced solution that integrates both student-centered approaches and resolves any conflicts between them [48]. Recent reports indicate that many medical students face challenges in manipulating models and concentrating on specific structures of interest in an online environment, raising questions about the effectiveness of these tools during a pandemic [49]. The lack of comprehensive studies evaluating the efficacy of online anatomy programs underscores the need for further research in this area.

The COVID-19 pandemic presents an opportunity to reassess the potential of these methods to deliver meaningful educational benefits. It also highlights the importance of exploring how the integration of new

technology into the medical curriculum can enhance students' learning experiences, rather than simply serving as an alternative [50]. Moreover, the integration of technology in anatomy education can potentially foster a more interactive and engaging learning environment. Interactive 3D models, virtual reality simulations, and augmented reality tools offer immersive experiences that can complement traditional learning methods [51]. These technological advancements can provide students with a deeper understanding of anatomical structures and their spatial relationships, which are crucial for clinical practice.

As medical education continues to evolve in response to the pandemic, it is essential to consider the long-term implications of these changes. The incorporation of technology in anatomy education should be guided by evidence-based practices and pedagogical principles that prioritize student engagement, active learning, and the development of clinical skills. By embracing innovative teaching methods and leveraging technological advancements, educators can ensure that anatomy education remains effective, relevant, and adaptable to the changing landscape of medical education.

Conclusions

The COVID-19 pandemic has profoundly influenced the traditional approach to medical education, necessitating immediate adaptation and innovation. The transition to online and remote learning, driven by the need for physical distancing and risk mitigation, presented significant challenges for educators and students, particularly in disciplines like anatomy, which rely heavily on practical experience. This period of disruption underscored the importance of flexibility and adaptability in medical education. Institutions rapidly modified their teaching and assessment methods to ensure the continuity of education and to protect the well-being of students and faculty.

This systematic review underscores the substantial changes in anatomy teaching methods during the COVID-19 pandemic. The review aimed to compare the methodologies employed before and during the pandemic, without attempting to assess whether online teaching is superior or inferior to pre-pandemic methods. Instead, the objective was to illuminate the adaptations and innovations that emerged in response to the unprecedented challenges faced in anatomy education.

The experiences gained during these challenging times are likely to catalyze a rethinking of traditional methods, moving anatomy education closer to technology-enhanced learning. E-learning, through the use of virtual software and 3D models, along with online learning platforms, was widely adopted by higher education institutions worldwide to avoid a lost academic year due to the pandemic. This shift presents an intriguing area for future study: the effectiveness of these technological modifications and their long-term impact on the quality of anatomy education.

Future research should evaluate the potential impact of these educational adaptations on students' clinical skills and professional development. The COVID-19 pandemic has been a pivotal moment in medical education, especially in approaches to teaching anatomy. For most educators, the shift to online and technology-enhanced learning may not be a temporary measure adopted due to the global crisis, but a tangible opportunity to change paradigms in educational practices. In this evolving landscape, medical schools must focus on maintaining the quality of education while developing competent health professionals ready to address emerging challenges in the field.

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