

MOST INTEGRATED VIRTUAL IMAGES OF THE BONES IN THE TEACHING OF HUMAN ANATOMY: ARE THERE ANY DIFFERENCES BETWEEN ONLINE AND ON-SITE TUTOR?

Dzintra Kazoka

Rīga Stradiņš University, Institute of Anatomy and Anthropology, Latvia

Mara Pilmane

Rīga Stradiņš University, Institute of Anatomy and Anthropology, Latvia

Abstract. *Covid-19 situation has seriously disrupted regular traditional methods and tools for Human Anatomy teaching. In order to replace limited access to the real human bones, anatomy educators increased integration and use of virtual images in comparison with the past study processes. The present study was conducted to review 15 Human Anatomy tutors' responses regarding the most used virtual images of the bones for online teaching from March 2020 to the end of October 2021 vs usual on-site teaching at the Department of Morphology. The interview was designed and feedback was taken from the tutors. The majority of the tutors added to their online practical classes a lot of virtual images from anatomical applications and different available resources, related directly to the isolated bones of the skull. For several tutors the searching, preparation and use of virtual images for online teaching was a novelty with advantages and disadvantages. Some tutors have used the possibilities presented by the pandemic to innovate their teaching of skull bones. Virtual images of the bones are an adequate resource for the early stages of undergraduate teaching, but the learning experience may be further enhanced by providing options for the studies with the use of real specimens.*

Keywords: *bones, Covid-19, online, on-site, tutors, virtual images.*

Introduction

Medical education is based on general study courses, including anatomy, (Azimi Khatibani & Tabatabai, 2021), where traditional teaching methods and study materials were widely used and accepted before the period of Covid-19. The unexpected and fast move from regular practical classes to online and remote teaching has changed the way of teaching in most of the Universities, including Rīga Stradiņš University (RSU).

Even before Covid-19, there was already adoption of the digital technologies in anatomy education but the pandemic period resulted in a challenge and an opportunity to use and assess remote teaching and e-studies, including all areas of distant communication and accelerated learning. In the world a lot of anatomists

have responded by necessarily forcing the students to remotely study, challenging their teaching methods and resources (Cortese & Frascio, 2021).

The increase in technological possibilities and resources for educational purposes allows the use of virtual images for improving anatomical knowledge in the field of medicine (Bartoletti-Stella et al., 2021). The use of different virtual images in various forms has always been intrinsically associated with Human Anatomy. Among the virtual tools, the images of the human bones could represent a valid resource that allows, through an online platform, to teach anatomy on-site and during a pandemic period.

During the last years, virtual images of human bones have undergone massive advances in anatomy and simulation-based training for clinical areas. Deep knowledge of skull bones is also essential for students in the medical and dentistry fields. Digital images of the skull bones may allow the opportunity to present detailed, high-quality details, classical and rare anatomical variants in different cross-sections. In this scenario, different images of the bones have been proposed for anatomical teaching, but they show several limitations in the education of human anatomy since their use is limited to specific anatomical topics.

The present study aimed to review Human Anatomy tutors' responses regarding the most used virtual images of the bones for online teaching and compare the use of these images in traditional on-site learning at the Department of Morphology of Rīga Stradiņš University (RSU).

Material and methods

The current study took place from March 2020 to the end of October 2021 at the Department of Morphology. The participants were 15 Human anatomy tutors who taught the study course of Skeletal System Anatomy for the first-year (1st semester) students from the Faculty of Medicine and Faculty of Dentistry. The selection of tutors was based on an open and voluntary invitation. The inclusion criteria were being a tutor in Human Anatomy, experience dealing with online and on-site studies, digital technologies and tools, and willingness to be interviewed.

In the pre-Covid-19 period and the first part of the 1st semester weekly the practical class consisted of three hours, including presentations and demonstrations of the anatomical structures on dried human bones and/or plastic models from materials of the Laboratory of Anatomy.

From March 2020, according to the transition to remotely teaching, the practical classes were changed to format for two-hours online weekly. The practical classes were performed by our tutors using the official e-studies platform of RSU, including prepared links for the online communication platform Zoom (Zoom Video Communications, Inc., San Jose, CA). In this format, tutors

presented the topics of the Skeletal System Anatomy for students online, including virtual images and PowerPoint slides. The anatomical structures were indicated on specially prepared, created and/or selected virtual images of the human bones together with plastic models when appropriate. There were also presented some difficult anatomical structures, including virtual images of the skull bones. Several virtual images were added from: “Complete Anatomy”, a three-dimensional (3D) e-anatomy software (created by “3D4Medical”) as a visual aid, DVD “Acland’s Atlas of Human Anatomy” (Acland, 2003) and an interactive anatomy learning platform “Anatomy Next” (RSU Anatomy app, 2020-2021).

This study was designed to get answers to the following questions:

- 1) What types of virtual images of the bones were used by tutors in the pre-Covid-19 or on-site teaching process of Human Anatomy?
- 2) What types of virtual images of the bones were used by tutors in the Covid-19 pandemic period or online teaching process of Human Anatomy?
- 3) What are the general differences between online and on-site anatomy tutors, using virtual images of the bones in traditional and remote practical classes?

An open-ended interview was the instrument used to collect data for the study. This procedure was conducted in a one-on-one event and this process took approximately 10 to 15 minutes. The structure of the interview was developed concerning the questions formulated for the study. The contents were made up of the experience characteristics of the Human Anatomy tutors based on on-site and online practical classes. Most of the asked questions were multiple choice type questions, where tutors were asked to choose the most appropriate option. Some questions were simple “yes/no” questions. There were also included options to give the tutors’ points of view. The interview continued until saturation, meaning no further data were obtained on the topics of interest.

All interviews were transcribed, and the answers of the tutors to questions were analyzed qualitatively, recoded depending on the thematic item and analyzed concerning the other answers.

The data resulting from the tutors’ interviews were analyzed by using thematic analysis of content as the most common technique for data analysis (Elo & Kyngäs, 2008), based on six steps model (Braun & Clarke, 2006). Differences between on-site and online tutors were detected when formulating the questions in five thematic items: the preferred way of teaching; characteristics of the used virtual images in the pre-Covid-19 period; characteristics of the used virtual images in the Covid-19 period; satisfaction with the effectiveness of the onsite practical classes in the pre-Covid-19 period; satisfaction with the effectiveness of the online practical classes in the Covid-19 period. According to the reflection of

the tutors' experiences, every item was formulated into five categories ranging from 1 (the lowest) to 5 (the highest).

The assessment of the similarities and differences was related to tutors' self-concept and several recommendations were formed for the future teaching process.

Results

Based on the results of the analysis, five thematic items represent a specific teaching experience that is important to online and on-site tutors, including their direct interaction with most integrated images of the bones. Five categories were extracted by the authors to display the thematic items discovered through analysis of tutors' responses. Their distributions are shown in Tables 1 – 3.

The thematic item of “the preferred way of teaching” comprised tutors' responses towards their experience using images of the bones in the Human Anatomy course (Table 1).

Table 1 Characteristics of tutors' responses on the 1st thematic item (created by the authors)

	Category				
Thematic item	1	2	3	4	5
Preferred way of teaching	textbooks	anatomical videos and free online resources, DVD “Acland’s Atlas of Human Anatomy”, the app “Anatomy Next”	virtual images available free online, demonstrations, PowerPoint presentations	software “Complete Anatomy”	materials provided by Laboratory of Anatomy

The 1st category included tutors' responses about the use of the textbooks: from the oldest in which there were only texts to be read, to more recent books containing different illustrations of the bones. Only some tutors used textbooks as an effective way of instructing and consulting students about bones, or for instructing and providing resources for students.

The 2nd category refers to the answers of the tutors who also indicated that different available anatomical videos and free online resources would be the other alternative for the teaching of the bones and their structures. Virtual images of the bones and videos were used by tutors from the DVD “Acland’s Atlas of Human Anatomy” and from virtual models with options for navigation through the images that were included in the app “Anatomy Next”. Several tutors indicated that there the characteristics and details of the corresponding anatomical structures of the bones were explained very well but they had a limited virtual experience in using these tools for teaching.

The 3rd category included answers where tutors agreed that virtual images of the bones available free online had helped them teach better. The images that were selected and used included bones of the following parts of the body: head, neck, thorax, back, upper and lower limbs. Responses showed that during the pandemic, demonstrations of the virtual images and PowerPoint presentations were more preferred by tutors as the best alternative option to teach Human Anatomy for students effectively. The most important was the fact that the tutors found sharing their selected and prepared virtual images and PowerPoint presentations between each other before the practical classes.

The 4th category refers to the answers of the tutors who found virtual images of the bones offered by software “Complete Anatomy” extremely useful for teaching. Tutors selected this platform for students to help them understand the anatomical structures of the bones because it was a convenient and modern tool that supplemented traditional educational delivery methods.

When asked to mention the preferred way of teaching the bones in practical classes, the answers included in the 5th category showed that most tutors reported materials provided by the Laboratory of Anatomy first. Tutors indicated that through the teaching process with real specimens, they could teach the best about the structures of the bones and made a real understanding of the 3D anatomy.

The 2nd and 3rd thematic items included five categories that were focused on “characteristics of the used virtual images in the pre-Covid-19 and in the Covid-19 periods” (Table 2).

Table 2 Characteristics of tutors’ responses on the 2nd and 3rd thematic items (created by the authors)

	Category				
Thematic item	1	2	3	4	5
Characteristics of the used virtual images in the pre-Covid-19 period	shoulder girdle	pelvic girdle	hand and foot	upper and lower limbs	skull, vertebral column, ribs
Characteristics of the used virtual images in the Covid-19 period	vertebral column, ribs	shoulder and pelvic girdle	upper and lower limbs	hand and foot	skull

Following the analysis of the tutors’ responses, the use of the virtual images related to the bones of the shoulder and pelvic girdles, hand and foot were the 1st, 2nd and 3rd categories that represented these types of the virtual images used for teaching in the pre-Covid-19 period. Only some tutors stated that they used these virtual images of the human bones because dried human bones were used in the practical classes.

When the tutors were asked about the types of the other virtual images that they intensively used and adopted for traditional teaching in the pre-Covid-19 period, these answers were included in the 4th and 5th categories. The majority of tutors used virtual images for topics about bones of the upper and lower limbs, skull, vertebral column and ribs. All tutors mentioned that the human skull was the most difficult topic to learn on-site. The majority of the used virtual images were related directly to the topics of the skull, including different cross-sections, isolated bones or most complicated bones (e.g., temporal bone with canals, ethmoid and sphenoid bones) and topographical places.

The use of virtual images in online practical classes increased during the Covid-19 period. This also included some changes in tutors' responses. The use of the virtual images related to the bones of the vertebral column, ribs, shoulder and pelvic girdles, upper and lower limbs were the 1st, 2nd and 3rd categories that represented these types of virtual images used for teaching in the Covid-19 period. These pictures were used by tutors for the detection of the parts, isolated bones, anatomical details, specific signs, identification and recognition between parts or right/left ribs' sides. The minority of our tutors used virtual images directly related to vertebral column and ribs.

The answers that were included in the 4th and 5th categories, showed that the majority of the tutors used virtual images related to the bones of the hand, foot and skull. The images of the hand and foot were helpful in the detection of small bones and details, locations, and relationships between bones.

The images of the skull were very important and useful for explanation and visualization of the isolated bones with parts and details, small openings and apertures, canals of the temporal bone, paranasal sinuses, topography, optic and nasal cavities, and cross-sections.

The 4th and 5th thematic items were related to tutors' responses on the satisfaction with the effectiveness of the on-site practical classes in the pre-Covid-19 period and online practical classes in the Covid-19 period (Table 3).

Table 3 Characteristics of tutors' responses on the 4th and 5th thematic items (created by the authors)

Thematic item	Category				
	1	2	3	4	5
Satisfaction with the effectiveness of the on-site practical classes in the pre-Covid-19 period	the app "Anatomy Next", videos from DVD "Acland's Atlas of Human Anatomy"	software "Complete Anatomy"	3D printed anatomical models of the bones	virtual dissection table "Anatamage"	real bones, cadavers, real dissections, combinations with digital possibilities

Satisfaction with the effectiveness of the online practical classes in the Covid-19 period	videos from DVD “Acland’s Atlas of Human Anatomy”	the app “Anatomy Next”	software “Complete Anatomy”	3D printed anatomical models of the bones	virtual images of the bones PowerPoint presentations
---	---	------------------------	-----------------------------	---	---

The answers about the use of the virtual images of the bones from the app “Anatomy Next” and videos from DVD “Acland’s Atlas of Human Anatomy”, digital materials from software “Complete Anatomy” and 3D printed anatomical models of the bones were included in the 1st, 2nd and 3rd categories in the pre-Covid-19 period.

The next category was related to the use of the new and innovative technologies by our tutors. The majority noted, that they included in the practical classes the use of the virtual dissection table “Anatomage” (Table Application software (Table EDU 6.0) from Anatomage, Inc., USA) with different digital tools and virtual dissections.

When the tutors were asked about the satisfaction of the effectiveness of on-site practical classes, most of them underlined that the use of real anatomical bones, cadavers and real dissections is without a doubt the gold standard for teaching anatomy. Throughout the on-site teaching period, all tutors had access to the osteological, cadaveric materials, mentioned in digital tools and platforms. The incorporation of virtual images, different animations and videos made the teaching of Human Anatomy more informative and interesting. All tutors noted that real materials with included digital possibilities made the students better prepared for the practical classes and stimulated the development of the touch and sight. The students were able to interact more with the tutors. In the pre-Covid-19 practical classes, tutors created a stronger and deeper explanation of the skeletal system, individual bones, differences in sizes, shapes, surfaces and other details for the students.

When assessing tutors’ responses about satisfaction with the effectiveness of online practical classes in the Covid-19 period, in Table 3 the 1st, the 2nd and 3rd categories were related to the use of videos from DVD “Acland’s Atlas of Human Anatomy”, virtual images of the bones from the app “Anatomy Next” and from software “Complete Anatomy”. The lack of visualization of the complex anatomical details made different skeletal materials more complicated for explanation and teaching of them in Human Anatomy. All tutors commented that they had to invest more time and effort into the searching, selection and preparing of the virtual images of the bones for the teaching during that time. According to this, conducting the online anatomy practical classes was a serious and challenging task. In addition, the majority of tutors stated that teaching Human

Anatomy without and/or limited cadaveric and bones demonstrations would lead to limited understanding of the general structures and their interconnections in the human body. After analysis of answers about tutors' views on the replacement of the traditional anatomical materials only with these virtual materials, the majority of tutors replied "no". However, part of the tutors declared that there could be a combination of the on-site and online materials for teaching.

Moreover, materials of the human bones used in routine practice were replaced by 3D printed anatomical models of the bones, virtual images and PowerPoint presentations (categories 4 and 5). Also, in the Covid-19 period, the majority of tutors declared that they began to use virtual images of the bones more often than before. The online classes were made more interactive by including the virtual images. As a part of the practical teaching, there were incorporated osteological visualizations and demonstrations of different anatomical structures and their locations. The images were used during the online sessions, and afterward, anatomical structures were explained step-by-step and discussed by tutors, including better and clear visualization of the bony landmarks and/or important muscular attachments.

Discussion

The Coronavirus disease 2019 (Covid-19) pandemic period impacted all aspects of the quantity and quality of medical education and resulted in a lot of challenges in different fields (Dedeilia et al., 2020). Institutions of higher education were found to utilize alternative methods of teaching effectively in this period time shifting away from the traditional ways (Nordmann et al., 2020). It is clear, that courses with components of the practical classes, including Human Anatomy, were especially burdened with providing online activities to replace traditional teaching and learning (McWatt, 2021). In practice tutors continued education process with the impact of the restrictions and limits due to Covid-19 (Kooloos, Bergman, Scheffers, Schepens-Franke, & Vorstenbosch, 2020). This period has also affected all medical professionals in their academic and/or professional development and training from the undergraduate level to postgraduate (Hau, Weitz, & Bork, 2020).

The findings of the different studies lead to the information and situation that the impact of the pandemic effects was limited by development, intensive support and use of digital technologies (Alhasan & Hasaneen, 2021). Different types of online tools should incorporate as much interactive technology as possible, to provide active, attractive and engaging teaching. The successful use of digital sources, platforms, apps and images can compensate for the pandemic effects and implement several new solutions. The special type of knowledge and skills could be used by educators to inform decisions about which supplemental resources are

effective for various teaching and learning purposes (Baptiste, Abramovich, & Browne, 2021).

There is a growing interest in online teaching in higher education but this has been more challenging in Human Anatomy. We know that anatomy is the oldest scientific discipline of medicine that has been always very close to other medical study courses. The accurate knowledge of anatomy is still cardinal in clinical courses. It is a complex 3D study course with a variety of specific and contextual challenges that depends primarily on the use of face-to-face classes, human cadaveric tissues for teaching and learning face-to-face during practical sessions (Jones, 2021). Direct or on-site studies of Human Anatomy via face-to-face with the use of cadaveric tissues have historically been an expectation for medical and health science students. The Covid-19 pandemic period has moved to self-isolation and social distancing that has made the teaching and learning of face-to-face anatomy difficult (Diaz, Linden, & Solyali, 2021).

During the time between the pre-pandemic and pandemic periods, the teaching and learning process was changed by the combination of different methods and types of technologies (Natsis et al., 2021). The challenges performed by Covid-19 can be interpreted as unique possibilities to test new materials, resources and methods against traditional teaching (Byrnes, Kiely, Dunne, McDermott, & Coffey, 2021). Several authors noted that tutors were trained in new online methodologies, and they showed interest in learning new teaching tools for teaching in the new reality and detected challenges (Verde & Valero, 2021). Tutor performance in the remote study process was influenced by several factors, including the time-consuming creation of materials for online teaching, the availability of technical support during the implementation of them in the e-studies and the wide range of strategies to facilitate distance education (Bani Hani et al., 2021). Many factors can also affect the efficiency of online learning (Hanafy, Jumaa, & Arafa, 2021), including in these studies a comparison of the difference in teaching and learning effectiveness between physical practical classes and online education in the past (Yu-Fong Chang, Wang, Lin, Cheng, & Chiang, 2021).

Until the pre-Covid-19 period, our anatomy tutors relied on face-to-face interactions for teaching and research activities, cadaveric prosections and virtual anatomy platforms. Despite challenges, the Covid-19 limitations present new opportunities to develop new anatomical educational resources, upskilling of tutors in new technologies and collaboration between each other and students. In the current crisis, mixed methods of teaching and learning anatomy are needed for different reasons (Franchi, 2020). In the field of anatomy, the art, drawing and images are interconnected together and form the cornerstone of education. Perhaps, because of the history that is related to gross anatomy and art, the necessity to display images transformed anatomy and moved to the early adoption of the Internet. Creating and developing content that fits in the curriculum of the

study course as well as engaging students through the virtual environment for tutors might appear to be complicated. Several visual learning resources and images being closely associated with text continued in the anatomy textbooks containing collections of images that show the human form and proportions. Despite this, how anatomy tutors and students create, access, view and interact with images has changed dramatically over the last 20 years (Hennessy & Smith, 2020). Different active learning strategies are increasingly utilized in the new and updated digital formats (Chen, Ayoob, Dessler, & Khurana, 2021). Medical students appreciate the opportunity to use new interactive models (Wu et al., 2020) or 3D-printed models (Kazoka, Pilmane, & Edelmers, 2021).

Human Anatomy is a study course with Latin terminology that students traditionally find complicated and labor-intensive. Even with such reduced time, medical students still have to identify and memorize a lot of anatomical structures (Chung et al., 2020). According to the complexity of several skull bones, increased and accelerated adoption of current images and rapid creation of new materials are now required. We should underline that the number and appearance of annotated anatomical structures must be identified and assessed on the created materials relative to the real specimens by experienced anatomy tutors (Li et al., 2020). This model can aid students in understanding complex anatomical structures better (Chen et al., 2020).

Our medical educators have rapidly changed their teaching methods and materials by moving as much online as possible in a digitalized format. There are studies, where authors underline that their approach consisted of not just making available other materials for students to use online during the Covid-19 period (Klein et al., 2019). Although in a remote model of the practical classes tutors should understand that the preparation of the students is important in the dynamic development of the study course (Reguera & Lopez, 2021). Tutors should consider students as the main persons in the practical classes while the tutors themselves play the leading role in the process of “teach by learning and research by teaching” (Liu et al., 2021). In face of the necessity to undertake online teaching, our tutors at all levels have had to undertake novel work for the use and creation of the digital images of the skull bones. Besides this, tutors are ready to teach online practical classes, and online teaching has opened anatomy tutors’ eyes to the possibilities offered by Zoom. Although it is clear that the effectiveness of remote teaching with the use of the digital images varies amongst tutors in different age groups. This fact highlights that some tutors without digital images, access to them and/or technologies can struggle to participate in the remote teaching process. We agree that medical educators, including anatomy tutors, should use what has been learned from the experience of this pandemic period and to perform positive educational changes for the future (Thom, Kimble, Qua, & Wish-Baratz, 2021).

This study was limited by its sample size but the five produced thematic items and five categories after analysis of tutors' responses were useful for the generation of some ideas, discussions of the topics, conclusions and recommendations.

Conclusions

While regular on-site classes with different anatomical materials were the norm in pre-Covid time, then the pandemic period for anatomy tutors was an opportunity to remind themselves about the knowledge, skills, materials and necessities such as adaptability, decision making and creative problem solving.

The findings of this study are useful for understanding different virtual images, including the skull bones, and their use and type that may suit us best depending on the anatomical topics, situations and/or needs of our students. It is clear that virtual images of the bones are an adequate resource for the early stages of undergraduate teaching but the learning experience may be further enhanced by providing options for the studies with the use of real specimens.

Besides this, in online practical classes tutors can not replace traditional teaching but the remote type of study process can be implemented in the Human Anatomy course like an additional tool.

Furthermore, future investigations can validate the conclusions of this study.

Acknowledgements

The authors would like to thank all Human Anatomy tutors for their work and experience during the transition period to remote teaching, their invested time and participation in this study.

References

- Alhasan, M., & Hasaneen, M. (2021). Digital imaging, technologies and artificial intelligence applications during COVID-19 pandemic. *Computerized Medical Imaging and Graphics*, 91, 101933. DOI: <https://doi.org/10.1016/j.compmedimag.2021.101933>
- Azimi Khatibani, S.E., & Tabatabai, S. (2021). Covid-19 impact on modern virtual pathology education: Challenges and opportunities. *Iranian Journal of Pathology*, 16(4), 439–443. DOI: <https://doi.org/10.30699/ijp.2021.525144.2589>
- Bani Hani, A., Hijazein, Y., Hadadin, H., Jarkas, A.K., Al-Tamimi, Z., Amarin, M., Shatarat, A., Abu Abeleh, M., & Al-Taher, R. (2021). E-Learning during COVID-19 pandemic; Turning a crisis into opportunity: A cross-sectional study at The University of Jordan. *Annals of Medicine and Surgery*, 70, 102882. DOI: <https://doi.org/10.1016/j.amsu.2021.102882>
- Baptiste, Y.M., Abramovich, S., & Browne, C.J. (2021). Measuring the value of a digital supplemental resource. *Advances in Physiology Education*, 45(4), 685–693. DOI: <https://doi.org/10.1152/advan.00080.2021>

- Bartoletti-Stella, A., Gatta, V., Mariani, G. A., Gobbi, P., Falconi, M., Manzoli, L., Faenza, I., & Salucci, S. (2021). Three-dimensional virtual anatomy as a new approach for medical student's learning. *International Journal of Environmental Research and Public Health*, 18(24), 13247. DOI: <https://doi.org/10.3390/ijerph182413247>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77–101. DOI: <https://doi.org/10.1191/1478088706qp063oa>
- Byrnes, K.G., Kiely, P.A., Dunne, C.P., McDermott, K.W., & Coffey, J.C. (2021). Communication, collaboration and contagion: “Virtualisation” of anatomy during COVID -19. *Clinical Anatomy*, 34(1), 82–89. DOI: <https://doi.org/10.1002/ca.23649>
- Chen, D., Ayoob, A., Desser, T. S., & Khurana, A. (2021). Review of learning tools for effective radiology education during the covid-19 era. *Academic Radiology*, 29(1), 129–136. DOI: <https://doi.org/10.1016/j.acra.2021.10.006>
- Chen, S., Zhu, J., Cheng, C., Pan, Z., Liu, L., Du, J., Shen, X., Shen, Z., Zhu, H., Liu, J., Yang, H., Ma, C., & Pan, H. (2020). Can virtual reality improve traditional anatomy education programmes? A mixed-methods study on the use of a 3D skull model. *BMC Medical Education*, 20(1), 395. DOI: <https://doi.org/10.1186/s12909-020-02255-6>
- Chung, B.S., Koh, K.S., Oh, C.-S., Park, J.S., Lee, J.-H., & Chung, M.S. (2020). Effects of reading a free electronic book on regional anatomy with schematics and mnemonics on student learning. *Journal of Korean Medical Science*, 35(6), e42. DOI: <https://doi.org/10.3346/jkms.2020.35.e42>
- Cortese, K., & Frascio, M. (2021). New settings in anatomy and surgery teaching during the covid-19 pandemic. *Anatomical Sciences Education*, 14(4), 430–431. DOI: <https://doi.org/10.1002/ase.2077>
- Dedeilia, A., Sotiropoulos, M.G., Hanrahan, J.G., Janga, D., Dedeilias, P., & Sideris, M. (2020). Medical and surgical education challenges and innovations in the covid-19 era: A systematic review. *In Vivo*, 34(3 suppl), 1603–1611. DOI: <https://doi.org/10.21873/invivo.11950>
- Diaz, C.M., Linden, K., & Solyali, V. (2021). Novel and innovative approaches to teaching human anatomy classes in an online environment during a pandemic. *Medical Science Educator*, 31(5), 1703–1713. DOI: <https://doi.org/10.1007/s40670-021-01363-2>
- Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107–115. DOI: <https://doi.org/10.1111/j.1365-2648.2007.04569.x>
- Franchi, T. (2020). The impact of the covid-19 pandemic on current anatomy education and future careers: A student's perspective. *Anatomical Sciences Education*, 13(3), 312–315. DOI: <https://doi.org/10.1002/ase.1966>
- Hanafy, S.M., Jumaa, M.I., & Arafa, M.A. (2021). A comparative study of online learning in response to the coronavirus disease 2019 pandemic versus conventional learning. *Saudi Medical Journal*, 42(3), 324–331. DOI: <https://doi.org/10.15537/smj.2021.42.3.20200741>
- Hau, H.-M., Weitz, J., & Bork, U. (2020). Impact of the covid-19 pandemic on student and resident teaching and training in surgical oncology. *Journal of Clinical Medicine*, 9(11), 3431. DOI: <https://doi.org/10.3390/jcm9113431>
- Hennessy, C.M., & Smith, C.F. (2020). Digital and social media in anatomy education. In P. M. Rea (Ed.), *Biomedical Visualisation* (Vol. 1320, pp. 109–122). Springer International Publishing. DOI: https://doi.org/10.1007/978-3-030-47483-6_6
- Jones, D.G. (2021). Anatomy in a post-covid-19 world: Tracing a new trajectory. *Anatomical Sciences Education*, 14(2), 148–153. DOI: <https://doi.org/10.1002/ase.2054>
- Kazoka, D., Pilmane, M., & Edelmers, E. (2021). Facilitating student understanding through incorporating digital images and 3d-printed models in a human anatomy course. *Education Sciences*, 11(8), 380. DOI: <https://doi.org/10.3390/educsci11080380>

- Klein, R., Tomassoni, C., Rajaaman, G., Winchester, M., Eizenberg, N., & Sinnayah, P. (2021). First year student perception and experience of online topographical anatomy laboratory classes using zoom technology during the covid-19 pandemic. *International Journal of Innovation in Science and Mathematics Education*, 29(3). DOI: <https://doi.org/10.30722/IJISME.29.03.002>
- Kooloos, J.G.M., Bergman, E.M., Scheffers, M.A.G.P., Schepens-Franke, A.N., & Vorstenbosch, M.A.T.M. (2020). The effect of passive and active education methods applied in repetition activities on the retention of anatomical knowledge. *Anatomical Sciences Education*, 13(4), 458–466. DOI: <https://doi.org/10.1002/ase.1924>
- Li, Q.-Y., Zhang, Q., Yan, C., He, Y., Phillip, M., Li, F., & Pan, A.-H. (2020). Evaluating phone camera and cloud service-based 3D imaging and printing of human bones for anatomical education. *BMJ Open*, 10(2), e034900. DOI: <https://doi.org/10.1136/bmjopen-2019-034900>
- Liu, Q., Sun, W., Du, C., Yang, L., Yuan, N., Cui, H., Song, W., & Ge, L. (2021). Medical morphology training using the xuexi tong platform during the covid-19 pandemic: Development and validation of a web-based teaching approach. *JMIR Medical Informatics*, 9(3), e24497. DOI: <https://doi.org/10.2196/24497>
- McWatt, S. C. (2021). Responding to Covid-19: A thematic analysis of students' perspectives on modified learning activities during an emergency transition to remote human anatomy education. *Anatomical Sciences Education*, 14(6), 721–738. DOI: <https://doi.org/10.1002/ase.2136>
- Natsis, K., Lazaridis, N., Kostares, M., Anastasopoulos, N., Chytas, D., Totlis, T., & Piagkou, M. (2021). “Dissection Educational Videos” (Devs) and their contribution in anatomy education: A students' perspective. *Surgical and Radiologic Anatomy*. DOI: <https://doi.org/10.1007/s00276-021-02829-z>
- Nordmann, E., Horlin, C., Hutchison, J., Murray, J.-A., Robson, L., Seery, M. K., & MacKay, J. R. D. (2020). Ten simple rules for supporting a temporary online pivot in higher education. *PLOS Computational Biology*, 16(10), e1008242. DOI: <https://doi.org/10.1371/journal.pcbi.1008242>
- Reguera, E.A.M., & Lopez, M. (2021). Using a digital whiteboard for student engagement in distance education. *Computers & Electrical Engineering*, 93, 107268. DOI: <https://doi.org/10.1016/j.compeleceng.2021.107268>
- Thom, M.L., Kimble, B.A., Qua, K., & Wish-Baratz, S. (2021). Is remote near-peer anatomy teaching an effective teaching strategy? Lessons learned from the transition to online learning during the Covid-19 pandemic. *Anatomical Sciences Education*, 14(5), 552–561. DOI: <https://doi.org/10.1002/ase.2122>
- Verde, A., & Valero, J.M. (2021). Teaching and learning modalities in higher education during the pandemic: Responses to coronavirus disease 2019 from Spain. *Frontiers in Psychology*, 12, 648592. DOI: <https://doi.org/10.3389/fpsyg.2021.648592>
- Wu, Y., Hikspoors, J.P.J.M., Mommen, G., Dabhoiwala, N.F., Hu, X., Tan, L., Zhang, S., & Lamers, W.H. (2020). Interactive three-dimensional teaching models of the female and male pelvic floor. *Clinical Anatomy*, 33(2), 275–285. DOI: <https://doi.org/10.1002/ca.23508>
- Yu-Fong Chang, J., Wang, L.-H., Lin, T.-C., Cheng, F.-C., & Chiang, C.-P. (2021). Comparison of learning effectiveness between physical classroom and online learning for dental education during the COVID-19 pandemic. *Journal of Dental Sciences*, 16(4), 1281–1289. DOI: <https://doi.org/10.1016/j.jds.2021.07.016>