ARTICLES
Archives of Veterinary Science
https://www.ufpr.br/

Perception of Veterinary Medicine Students Regarding the Use of a 3D Model of the Canine Brain in Learning Neuroanatomy: a Pilot Study

Submitted: *03/02/2025*
Accepted: *13/06/2025*

Bárbara Beatriz Garcia Santos[1], *Fernanda Nishina Terumi*[2], *Saulo Henrique Weber*[3], *João Armando Brancher*[4], *Maria Fernanda Pioli Torres*[5*], *Édison Luiz Prisco Farias*[6]

[1]*Departament of Anatomy, Federal University of Paraná (UFPR), Biological Sciences Sector, Polytechnic Center, Curitiba, Paraná, Brazil, e-mail: barbarabgarcias@gmail.com. ORCID: https://orcid.org/0009-0009-7018-7978*
[2]*Departament of Anatomy, Federal University of Paraná (UFPR), Biological Sciences Sector, Polytechnic Center, Curitiba, Paraná, Brazil, e-mail: ftnishina@gmail.com. ORCID: https://orcid.org/0009-0006-5909-8331*
[3]*Postgraduate Program in Animal Science and Biotechnology, Pontifical Catholic University of Paraná (PUCPR), Curitiba, Paraná, Brazil. e-mail: saulo.weber@pucpr.br. ORCID: https://orcid.org/0000-0002-7584-8044*
[4]*Postgraduate Program in Cell and Molecular Biology, Federal University of Parana, Federal University of Paraná (UFPR), Biological Sciences Sector, Polytechnic Center, Curitiba, Paraná, Brazil, e-mail: joaobrancher@ufpr.br, ORCID: https://orcid.org/0000-0002-8914-702X*
[5]*Departament of Anatomy, Federal University of Paraná (UFPR), Biological Sciences Sector, Polytechnic Center, Curitiba, Paraná, Brazil, e-mail: mariafernanda@ufpr.br. ORCID: https://orcid.org/0000-0001-9955-6647*
[6]*Departament of Anatomy, Federal University of Paraná (UFPR), Biological Sciences Sector, Polytechnic Center, Curitiba, Paraná, Brazil, e-mail: elpfarias@ufpr.br. ORCID: https://orcid.org/0000-0002-2968-7710*

[*]Author for correspondence e-mail: mariafernanda@ufpr.br

Abstract: Despite theoretical classes and studies with cadaveric models, understanding the brain, particularly cranial nerves (CNs), remains challenging for veterinary medical students. This study evaluated undergraduate veterinary students' perceptions of a 3D-printed brain model for neuroanatomical learning. The canine brain was scanned using KIRI Engine software with a smartphone camera. The images were exported and processed in Autodesk Meshmixer software to refine the 3D mesh. This was followed by printing planning in Ultimaker Cura software and production in polylactic acid (PLA) filament on a Creality Ender 3 printer. The model was tested in neuroanatomy classes, and students' perceptions were collected via a Likert scale-based questionnaire with 20 statements. Statistical analyses were performed via IBM 2017, Version 25.0. Statistical analyses included Spearman's correlation significance at $p < 0.05$ and the Mann–Whitney test. Twenty-nine students (25 women and four men) participated in the evaluation. The results revealed significant correlations: the "3D model helped me understand" with the "identified CN" ($p = 0.0285$), "made easier to understand" ($p = 0.0066$), and "understanding CN positioning better than anatomical natural material" ($p = 0.0141$). The students found the 3D model more helpful than the natural brain alone ($p = 0.0455$) and effective in representing brain characteristics ($p = 0.0002$). However, the model's texture was noted as a limitation ($p = 0.0433$). The students appreciated the 3D model as a valuable complement to neuroanatomy classes. While it has improved the understanding of the CN and other brain structures, the 3D model should be used as a supplementary tool in conjunction with other traditional teaching methods.

Keywords: Neuroanatomy, veterinary education, 3D model, additive manufacturing.

1. Introduction

Anatomy is considered a fundamental science for understanding basic medical principles, including the performance and interpretation of physical examinations (Sugand et al., 2010), as well as being essential for forming clinical reasoning (Turney, 2007). Due to its importance, anatomy is a necessary discipline in the curriculum of health courses (Aridan et al., 2023) and is typically introduced at the beginning of undergraduate studies. Teaching and learning anatomy involve theoretical classes followed by laboratory practices with pieces from cadaveric dissection (Turney, 2007; Abulaban et al., 2015; Rocha et al., 2021), with cadaveric dissection being necessary for improving medical skills since it allows for a three-dimensional understanding of anatomical structures (Ghosh, 2016), provides for the improvement of manual and cognitive skills (Sugand et al., 2010), and provides students with self-directed learning focused on accessing underlying tissues and organs that are fundamental to training surgical techniques essential to the success of any operative procedure (Turney, 2007; Baskaran et al., 2016).

On the other hand, the difficulty in accessing and storing cadavers, the deterioration of the material, and the production of chemical waste resulting from the storage and conservation of anatomical parts sometimes limit the use of the parts, consequently impacting the teaching-learning process of anatomy (Rocha et al., 2021). In this sense, alternative learning methods have been developed, mainly related to the use of digital technologies that allow the application of playful, educational activities with the use of images and educational games (Rocha et al., 2021), videos and virtual resources (Pandey & Zimitat, 2007; Pawlina & Drake, 2013), virtual reality (Aridan et al., 2023), augmented reality (Henssen et al., 2019), and three-dimensional (3D) printing models (Knoedler et al., 2015).

Concerning 3D printing, also called additive manufacturing, printing models obtained from this technique have been widely used in innovative teaching methodologies (Garas et al., 2018; Tripodi et al., 2020), contributing significantly to the training of surgical techniques (Bento et al., 2019), surgical planning with prosthetic reconstruction (Carretero et al., 2022), neurosurgery (Baskaran et al., 2016), and dental treatments (Ortensi et al., 2022). 3D-printed models have revolutionized teaching and training in hospitals and large clinical centers worldwide; however, the literature on the use of these models for teaching and learning in

https://doi.org/10.5380/avs.v30i2.98315

undergraduate veterinary medicine courses remains scarce. Regarding the study of neuroanatomy, a comprehensive understanding of microstructures is even more difficult due to the difficulty in identifying the origin and intracranial course of the nerves.

In this sense, the study of neuroanatomy, despite the efforts of professors, is considered extremely difficult by academics in human medicine (Abulaban et al., 2015) and veterinary medicine (Schoenfeld-Tacher et al., 2017). Some reasons why it is challenging to learn neuroanatomy in cadavers are the visualization of small structures or insufficient anatomical detail of the central nervous system, including the brain and spinal cord (Cheung et al., 2021), as well as the difficulty in dissecting nerves, since they are highly delicate parts and difficult to identify (Cheung et al., 2021; Lieu et al., 2018), especially in small species, such as dogs. Learning neuroanatomy has become so stigmatized that, in the early 1990s, Jozefowicz (1994) attributed to it a condition observed in academics, “neurophobia”. Given that nervous tissue is extremely delicate and can be damaged by handling, this study aimed to produce 3D models of canine brains from the digitalization of natural organs and assess the benefit of 3D printed models in the teaching-learning process of veterinary neuroanatomy.

2. Materials and Methods

This research was approved by the Research Ethics Committee of UFPR (protocol 69288423.7.0000.0102, 24/07/2023). Second- and third-semester students in the veterinary medicine course at UFPR were included in the study, and a free and informed consent form was obtained from all participants. A canine brain from the Anatomy Department of the Federal University of Paraná was selected for this study. This anatomical specimen was dissected and preserved in 10% formaldehyde for practical studies in the veterinary anatomy laboratory. It was chosen because it exhibited anatomical structures in good condition, such as the cerebral hemispheres, the brainstem, and, mainly, the apparent origin of the cranial nerves. The construction of the model involved scanning the brain, editing and correcting the 3D mesh, planning and printing the 3D model, and post-processing with the addition of painted cranial nerves. The steps are detailed below.

2.1. Brain scanning

The brain was scanned using the free KIRI Engine software, available for iOS, version 3.7.7 (Tokyo, Japan), via a smartphone camera (iPhone 11, Apple, Inc., Cupertino, United States of America). The brain was suspended using nylon threads to facilitate the photography scanning of all the anatomical axes and planes. More than 50 brain images were captured directly in the application, and the photographic files, 3D mesh, and texture were exported in JPG, OBJ, and MTL extensions, respectively.

2.2. 3D mesh editing and correction

The OBJ file was imported into Autodesk Meshmixer software version 3.5.474 (San Rafael, United States) to edit and correct the 3D mesh. Mesh correction and reproduction of neuroanatomy were based on the methods of DeLahunta, Glass, and Kent (2021), Dewey and Da Costa (2016), and Dyce et al. (2010). The anatomical structures and cranial nerves were highlighted with different “sculpt” tool brushes. The generated files were exported in Standard Tessellation Language (STL) format (Figure 1).

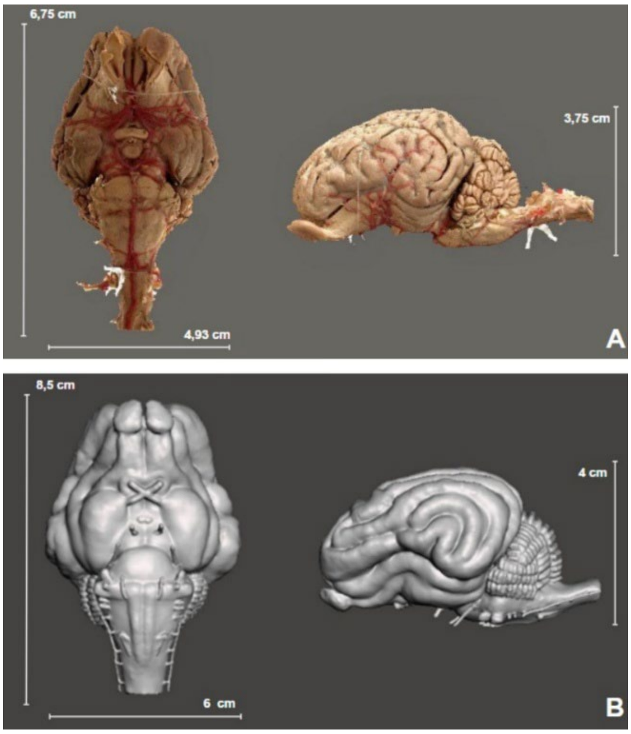

Figure 1 – Meshmixer software interface showing the textured 3D object before editing (A) and after organic modeling for reconstruction and highlighting of cranial nerves and mesh correction (B) in ventral and left lateral views.

2.3. Planning and 3D Printing

The 3D printing process was planned to use Ultimaker Cura software, version 5.7.1 (Utrecht, Netherlands), where the printing parameters were established. The model was sliced for printing with polylactic acid (PLA) filament, 0.12mm layer height, and 5% infill on a Creality Ender 3 printer (Shenzhen, China. Five copies of the 3D models were printed with measurements of 8.5 cm on the x-axis, 6 cm on the y-axis, and 4 cm on the z-axis.

2.4. Postprocessing

During postprocessing, the 12 pairs of sensory, motor, and mixed cranial nerves were highlighted by painting them in blue, red, and yellow, respectively. The details are shown in Figure 2.

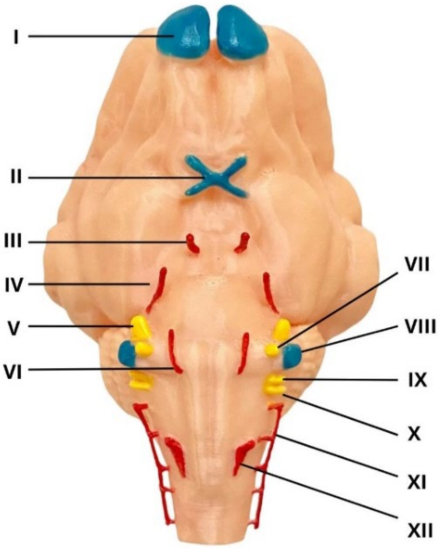

Figure 2 – Sensory nerves in blue: olfactory nerve (I), optic nerve (II), and vestibulocochlear nerve (VIII); motor nerves in red: oculomotor nerve (III), trochlear nerve (IV), abducens nerve (VI), accessory nerve (XI) and hypoglossal nerve (XII); mixed nerves in yellow: trigeminal nerve (V), facial nerve (VII), glossopharyngeal nerve (IX) and vagus nerve (X).

2.5. Design of the learning activity

A class on the central nervous system was selected to test the students' perceptions of 3D-printed brain models, and a sample of veterinary medicine students was invited to participate in the activity. First, the students had a theoretical class in which they could assess the essential information concerning the anatomical organization of the central nervous system. This phase was the passive phase of the study, lasting 90 minutes. Next, the students proceeded to the practical activities. In this phase, the students were divided into groups of 4 or 5 participants. Each group received cadaveric parts and 3D-printed models, allowing them to assess the materials. This phase was active and lasted 60 minutes. Afterward, each student received a form with statements in which they individually expressed their opinion regarding the 3D models. The methodology was based on the work of Valverde et al. (2022), which investigates the use of crisscross heart three-dimensional printed models in medical education.

2.6. Assessment of students' perceptions of 3D printed models

The students' perceptions were assessed via a form containing 20 statements, the answers to which followed a Likert scale, whose opinions could range from 1 to 5: (1) agree, (2) Partially agree, (3) Neither agree nor disagree, (4) Partially disagree and (5) disagree. The statements used are shown in Table 1.

Statements 14 and 19 were included as verification statements, in which the preference for natural parts (statement 14) was verified concerning the use of the 3D model (statement 19), and the scores assigned were inverted. The researchers prepared questions to assess students' ability to understand the neuroanatomical location of the cranial nerves by comparing a 3D model with dissected parts. The following table shows the methodological sequence for assessing students' perceptions.

Statements
S1. The 3D model improved the understanding of the positioning of the cranial nerves in the brain.
S2. The 3D model helped to understand the difference between the real origin and apparent origin of the cranial nerves in the brain.
S3. The 3D model helped me to understand more about the neuroanatomy of the cranial nerves compared to using images from books.
S4. With the 3D model, it was easier to understand the anatomy of the cranial nerves than using only the anatomical parts.
S5. The 3D model facilitated the identification and neuroanatomical location of the 12 pairs of cranial nerves in the brain.

S6. With the 3D model it was easier to learn the anatomical location of the cranial nerves.
S7. The anatomical parts helped visualize the cranial nerves better in the 3D model.
S8. The 3D model made it easier to understand the apparent origin of the cranial nerves.
S9. Only by using the anatomical pieces can the position of the cranial nerves in the brain be differentiated.
S10. In addition to the cranial nerves, the 3D model helped with the neuroanatomy of other structures in the brain, such as the pons and the trapezoid body.
S11. The anatomical features were well represented in the 3D model.
S12. The color of the 3D model did not hinder the understanding of the organ's anatomy.
S13. The texture of the 3D model did not make a difference in learning the organ's anatomy.
S14. Understanding the brain structures and the location of the cranial nerves was better using only the anatomical pieces
S15. I would use the 3D model again to study anatomy.
S16. The 3D model can replace natural parts/cadavers for studying anatomy.
S17. I want to acquire a 3D model for my study.
S18. The 3D model is useful in the study of other subjects.
S19. The exploration of the 3D model is preferable to the natural organ.
S20. The exploration of the 3D model is preferable to the study of images.

Table 1 – Statements proposed to students aim to verify their perception regarding the 3D model.

2.7. Statistical analysis

The statistical analysis was based on Spearman's correlation between all questions in the questionnaire, with correlations between questions with a p-value <0.05 being considered significant. The Mann–Whitney test was used to compare the population variables of the research participants. Statistical analyses were performed by IBM 2017, SPSS Statistics for Windows, Version 25.0 (Armonk, United States of America).

3. Results

Twenty-nine students, 25 women (86%) and four men (14%), with an average age of 20.8 years, participated in this study. Of these, 23 were in the 2nd semester, and six were in the 3rd semester of the undergraduate course; 10 participants (2.9%) had previously studied anatomy, and 19 participants (66%) had no previous contact with neuroanatomy. Regarding gender, no statistically significant difference was observed in the responses given by the students ($p = 0.171$), despite the fact that only four individuals were male. Similarly, no significant differences were observed in the reactions between students who had and those who had not had any previous contact with neuroanatomy ($p = 0.944$).

Table 2 and Figure 3 present the individual responses of the 29 study participants. One hundred percent of the participants agreed that the 3D model improved their understanding of the anatomical location and facilitated the identification of the origins of the 12 pairs of cranial nerves (statements 1, 5, and 6). Similarly, the students agreed that the anatomical models helped them better understand neuroanatomy than the images in books (question 3) and the apparent origin of the cranial nerves (question 8). In the Spearman correlation analysis, it was possible to verify an association between statements “3D model helped me to understand more about the neuroanatomy” and “3D model facilitated the identification of the 12 pairs of CNs” (statements 3 and 5; $r= 0.414$; $p = 0.0285$) and statements 3 and 8, which correlated positively, highlighting that the use of the 3D model helped in the understanding of neuroanatomy about the use of 2D images ($r= 0.5136$; $p= 0.0066$).

Another relevant piece of information involves the results observed when the analysis is performed by associating statements 1 and 4. The results revealed that the responses were positively correlated, indicating that the 3D model improved the understanding of the location of the cranial nerves (statement 1) compared with the use of only the anatomical pieces (statement 4) ($r = 0.4638$; $p = 0.0141$). The relevance of the 3D model for understanding neuroanatomy concerning the use of only the anatomical pieces was also proven by the positive and significant correlation of statements 4 and 5 ($r = 0.3779$; $p = 0.0455$) and questions 9 and 14 ($r = 0.477$; $p = 0.0116$).

The 3D model also adequately represented the anatomical characteristics of the brain. This finding is due to the positive correlation between the statements “3D model helped with the neuroanatomy of other structures in the brain” and “the anatomical features were well represented in the 3D model” (statements 10 and 11; $r = 0.6989$; $p = 0.0002$). Finally, a negative correlation was found between questions 13 and 18 (-0.3819; $p = 0.0433$), indicating that the 3D model is helpful for other disciplines, but texture can be a limiting factor in the learning process. However, questions 13 and 14, although also showing a negative correlation ($r = -0.4104$; $p = 0.0299$), contradict the previous data, as the participants demonstrated a better understanding of the cranial nerves when the texture was used in conjunction with teaching, rather than when anatomical parts were used alone.

Regarding the influence of the color and texture characteristics of the 3D models, the participants agreed (26; 90%) and partially agreed (3; 10%) that the color of the 3D model did not hinder the understanding of the anatomy of the natural brain (statement 12), whereas only 45% (13) indicated that the texture of the model did not hinder the study (statement 13), suggesting that texture is relevant in defining the characteristics of the 3D models that are more faithful to the original part.

Statements 14 and 19, which were included as verification questions, showed that only one participant scored 1 and 2 for all the questions, suggesting that only this participant was inattentive when reading and responding to the assessment. Furthermore, statements 9 and 16 indicate that isolating the 3D model and the cadaveric specimen is not as helpful in learning about cranial nerves. Still, they emphasize that improving teaching is based on the complementarity of both methodologies, as shown in question 16, in which 59% (17) of the participants disagreed with the permanent replacement of anatomical parts by the 3D model.

Likert	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
1	28	14	24	24	28	27	19	20	1	11	20	26	13	1	27	1	27	17	0	15
2	1	10	5	3	1	2	6	8	6	10	7	3	7	5	1	4	1	6	7	10
3	0	2	0	2	0	0	3	1	4	7	1	0	3	3	0	7	0	5	7	3
4	0	3	0	0	0	0	0	0	10	1	1	0	3	6	1	5	1	1	11	1
5	0	0	0	0	0	0	1	0	8	0	0	0	3	14	0	12	0	0	4	0

Table 2 - Response patterns of the 28 participants to the 20 questions (S1 – S20) in the questionnaire. (1) totally agree, (2) partially agree, (3) indifferent, (4) partially disagree, and (5) totally disagree.

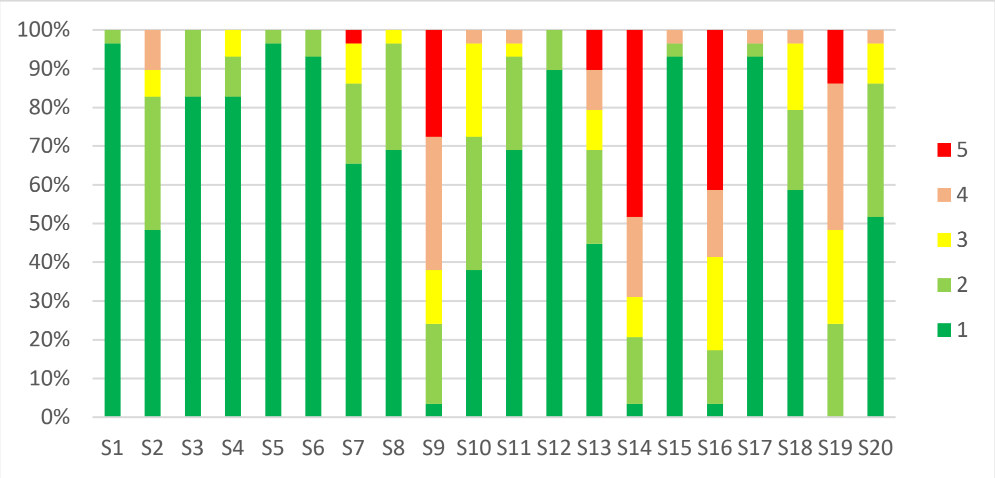

Figure 3 – Graph showing the pattern of responses of the 28 participants to the 20 questions in the questionnaire in percentage values: (1) totally agree, (2) partially agree, (3) indifferent, (4) partially disagree, and (5) totally disagree.

4. Discussion

Introducing 3D-printed models into the teaching and learning process has proven to be a valuable asset in various areas of education (Garas et al., 2018). Nonetheless, several uncertainties limit the introduction of models in daily practice, and few prospective studies have examined students' perspectives on using 3D models in combination with natural cadaveric pieces for study. In this sense, this study aimed to produce and introduce 3D models of canine brains in the teaching-learning process of neuroanatomy classes. The main results offer valuable insights into the application of these models in veterinary neuroanatomy.

First, it is essential to highlight that, in the opinion of the authors of this work, replacing cadavers with models for learning anatomy is not indicated in all cases but is a strategy that has the same advantages when combined with the use of cadaveric parts. This hybrid approach could offer the best of both options, combining the tactile learning and variability provided by cadavers with the advantages of repeated practice, improved visualization, and accessibility that models offer (Lieu et al., 2018; Björk, 2019; Silveira et al., 2021). In addition, using 3D models in the study of anatomy contributes to reducing the production of chemical waste, particularly compared with traditional cadaver-based dissection methods. The primary reasons for this are the reduced need for embalming chemicals and other toxic substances used in preserving cadavers, as well as the reduction of disposable materials that would typically be used in dissecting cadavers (Kaufman et al., 2007; De Caro et al., 2013; Tsingos et al., 2014). Printed models can make them more accessible for educational institutions, especially in resource-limited settings.

On the other hand, the focus of this research, in addition to producing models, is to collect information about students' perceptions when using them, and the results are promising. One particular point of interest was identifying the origin of the cranial nerves in the brain. The tested models appeared to aid in understanding the spatial morphology of the brain and the origin of the cranial nerves. This conclusion is based on the individual and combined statistical analysis of the opinions expressed by the students. This finding reinforces previous studies that showed that 3D models provide an interactive and manipulable environment where students can handle the model and visualize the structures from any angle, which is undoubtedly an advantage over 2D images (Pandey & Zimitat, 2007; Moore et al., 2019; Gil et al., 2020; Tripodi et al., 2020).

Since the 3D model was evaluated by undergraduate students, most of whom lacked in-depth knowledge of neuroanatomy, the authors of this work were primarily concerned with creating a pedagogical model that accurately represented the dog's brain anatomy. In this sense, the entire process of scanning, mesh editing, correction, printing, and post-printing analysis of the model was monitored by experts and professors with extensive experience in neuroanatomy teaching. Only after the favorable assessment were the models available to the students who participated in the research. In this sense, regarding the anatomical representation of the structures on the 3D model, there was no doubt about the student's satisfaction with the details presented in the model and their feelings about its effectiveness.

Unsurprisingly, opinions concerning model texture were the main negative points cited by the participants of this study. The model's texture directly correlates with the malleability of the material used in the printer and is an essential characteristic for processing tactile stimuli (Huang & Lin, 2017). Less malleable materials, such as the polylactic acid filament used in this work, directly interfere with the tactile perception of the piece, thereby reducing the sensory experience. Schoenfeld-Tacher et al. (2017) also compared the use of plastinated canine brain models and 3D-printed models and reported that the texture of 3D-printed models did not guarantee tactile stimulation. Because of visual and tactile factors, organ plastination is a traditional anatomical teaching method that can present greater authenticity to cadaveric parts. Still, it requires the use of chemicals that generate the waste mentioned above. New materials, such as thermoplastic polyurethane, which is characterized by its softness and flexibility (Samat et al., 2021), can serve as alternatives for printing models. Our research group has already tested other materials.

Among the advantages that 3D models offer to teaching include a reduction in the use of animals (Schoenfeld-Tacher et al., 2017), better visualization of small structures (Rocha et al., 2021), and a reduction in ethical and legal requirements for obtaining cadavers (Tripodi et al., 2020; Rocha et al., 2021). This may explain why 41% of the participants agreed with the permanent replacement of anatomical parts by the 3D model. However, most students indicate that 3D models do not entirely replace natural parts and the practice of dissection, an idea already defended in previous studies (Schoenfeld-Tacher et al., 2017; Silveira et al., 2021). Cadaveric dissection is irreplaceable and essential for learning anatomy (Ghosh, 2016; Rocha et al., 2021). However, our study revealed that the students agreed with exploring 3D models and cadaveric parts.

Finally, the production of the 3D model was the most time-consuming part of this study. Several standards for 3D printing, including file formats, combined materials, and colors, are challenging. However, with the image files ready, printing new models is a significantly more straightforward, accessible, and low-cost method that makes the use of printed models a viable alternative for replacing cadaveric parts.

5. Conclusion

Based on the analysis of the opinions expressed by the students, the 3D model in neuroanatomy classes was well received by most participants, as it facilitated the spatial visualization of important anatomical details. However, the models needed to be improved, especially in terms of the materials' texture. In addition, the models allowed the students to handle them more easily, bringing them closer to the natural brain. However, most students believe that 3D models cannot replace natural parts for studying anatomy and should instead function as adjuvants in the learning process.

Acknowledgments: This study was conducted with financial support from the Federal University of Parana (UFPR), from its Pro-Rectory for Extension and Culture (PROEC 08/2022) and its Pro-Rectory for Planning and Finance through the Academic Development Fund (FDA 2023-2024). The translation and revision of this article were carried out using Grammarly.

6. References

Abulaban, A.A. et al. Neurophobia among medical students. *Neurosciences (Riyadh, Saudi Arabia)*, v. 20, n. 1, p. 37–40, 1 Jan. 2015.

Aridan, N. et al. Neuroanatomy in virtual reality: Development and pedagogical evaluation of photogrammetry-based 3D brain models. *Anatomical Sciences Education*, 23 Nov. 2023. Available at: https://doi.org/10.1002/ase.2359.

Autodesk Meshmixer (Autodesk Inc., San Rafael, CA, United States) version 3.5.474.

Baskaran, V. et al. Current Applications and Future Perspectives of the Use of 3D Printing in Anatomical Training and Neurosurgery. *Frontiers in Neuroanatomy,* v. 10, 24 Jun. 2016.

Bento, R. B. et al. Otobone®: Three-dimensional printed Temporal Bone Biomodel for Simulation of Surgical Procedures. *International Archives of Otorhinolaryngology*, v. 23, n. 04, p. e451–e454, 31 maio 2019.

Björk, L. (2019) in "Combining cadaveric dissection with digital anatomy: a systematic review of educational approaches." Anatomical Science Education, 12(5), 421–430.

Carretero, J. L. C. et al. Virtual Surgical Planning and Customized Subperiosteal Titanium Maxillary Implant (CSTMI) for Three-Dimensional Reconstruction and Dental Implants of Maxillary Defects after Oncological Resection: Case Series. *Journal of Clinical Medicine*, v. 11, n. 15, p. 4594, 6 ago. 2022.

Cheung, C.C.; Bridges, S.M.; Tipoe, G.L. Why is Anatomy Difficult to Learn? The Implications for Undergraduate Medical Curricula. *Anatomical Sciences Education*, v. 14, n. 6, 2 Apr. 2021.

De Caro, R., et al. (2013). *Anatomical education in the 21st century: a new approach. Clinical Anatomy*, 26(2), 276–287

DeLahunta, A.; Glass, E.; Kent, M. *De Lahunta's veterinary neuroanatomy and clinical neurology*. Philadelphia, PA: Elsevier, 2021. ISBN 9780323696111

Dewey, C.W. and Da Costa, R.C. *Practical guide to canine and feline neurology*. [*S. l.*]: Wiley & Sons, Incorporated, John, 2015. ISBN 9781119062226.

Dyce, K. M. et al. *Tratado de Anatomia Veterinária*. Rio De Janeiro, RJ: Elsevier, 2010. ISBN 978-8535236729

Garas, M. et al. 3D-Printed specimens as a valuable tool in anatomy education: A pilot study. *Annals of Anatomy - Anatomischer Anzeiger*, v. 219, p. 57–64, set. 2018.

Ghosh, S.K. Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anatomical Sciences Education*, v. 10, n. 3, p. 286–299, 30 ago. 2016.

Gill, D.D., et al. (2020). "Ethical alternatives to traditional dissection in veterinary education." Journal of Veterinary Medical Education, 47 (4), 426 – 434.

Henssen, D.J.H.A. et al. Neuroanatomy Learning: Augmented Reality vs. Cross-Sections. *Anatomical Sciences Education*, v. 13, n. 3, p. 353–365, 19 Jul. 2019.

Huang, T.C; Lin, C.Y. From 3D modeling to 3D printing: Development of a differentiated spatial ability teaching model. *Telematics and Informatics*, v. 34, n. 2, p. 604–613, maio 2017.

Jozefowicz, R. F. Neurophobia: The Fear of Neurology Among Medical Students. *Archives of Neurology*, v. 51, n. 4, p. 328–329, 1 Apr. 1994.

Kaufman, J. J., et al. (2007). *Virtual reality and 3D printing in anatomy education: past, present, and future*. *Medical Teacher*, 29(10), e325–e333.

KIRI Engine: 3D Scanner. v. 3.7.7, KIRI Innovation (Hong Kong) Limited (kiriengine.app).

Knoedler, M. et al. Individualized Physical 3-dimensional Kidney Tumor Models Constructed From 3-dimensional Printers Result in Improved Trainee Anatomic Understanding. *Urology*, v. 85, n. 6, p. 1257–1262, 1 Jun. 2015.

Lieu, R. M.; Gutierrez, A.; Shaffer, J. F. Student Perceived Difficulties in Learning Organ Systems in an Undergraduate Human Anatomy Course. *HAPS Educator*, v. 22, n. 1, p. 84–92, Apr. 2018.

Moore, S. D., et al. (2019). "Veterinary anatomy in the 21st century: Integration of 3D technology into veterinary education." *Journal of Veterinary Medical Education*, 46(2), 115-124.

Ortensi, L. et al. Digital planning of composite customized veneers using Digital Smile Design: Evaluation of its accuracy and manufacturing. Clinical and Experimental Dental Research, v. 8, n. 2, p. 537–543, 1 Apr. 2022.

Pandey, P.; Zimitat, C. Medical students' learning of anatomy: memorization, understanding and visualization. *Medical Education*, v. 41, n. 1, p. 7–14, Jan. 2007.

Pawlina, W.; Drake, R. L. Anatomical models: Don't banish them from the anatomy laboratory yet. *Anatomical Sciences Education*, v. 6, n. 4, p. 209–210, Jul. 2013.

Rocha, D.P. et al. Métodos alternativos para o ensino da anatomia humana: revisão sistematizada. *Research, Society and Development,* v. 10, n. 16, p. e370101623641, 14 dez. 2021.

Samat, A.A. et al. Mechanical Properties and In Vitro Evaluation of Thermoplastic Polyurethane and Polylactic Acid Blend for Fabrication of 3D Filaments for Tracheal Tissue Engineering. *Polymers*, v. 13, n. 18, p. 3087, 13 Set. 2021.

Schoenfeld-Tacher, R.M. et al. Evaluation of 3D Additively Manufactured Canine Brain Models for Teaching Veterinary Neuroanatomy. *Journal of Veterinary Medical Education*, v. 44, n. 4, p. 612–619, Nov. 2017.

Silveira; E.E. et al. Canine Skull Digitalization and Three-Dimensional Printing as an Educational Tool for Anatomical Study. *Journal of Veterinary Medical Education*, v. 48, n. 6, p. 649–655, 1 Dez. 2021.

Statistica (Sistema de Software de Análise de Dados). 2006. v.7.1., StatSoft, Inc., EUA (StatSoft.com).

Sugand, K. et al. The anatomy of anatomy: A review for its modernization. *Anatomical Sciences Education*, v. 3, n. 2, p. 83–93, 2010.

Tripodi, N. et al. The Impact of Three-Dimensional Printed Anatomical Models on First-Year Student Engagement in a Block Mode Delivery. *Anatomical Sciences Education,* v. 13, n. 6, p. 769–777, 16 Apr. 2020.

Tsingos, T., et al. (2014). *The sustainability of virtual cadavers in medical education*. *International Journal of Medical Education*, 5, 92–99.

Turney, B. Anatomy in a Modern Medical Curriculum. *The Annals of The Royal College of Surgeons of England*, v. 89, n. 2, p. 104–107, Mar. 2007.

UltiMaker Cura. v.5.7.1, Ultimaker, Inc. (ultimaker.com).

Valberve, I. et al. Criss-cross heart three-dimensional printed models in medical education: A multicenter study on their value as a supporting tool to conventional imaging. *Anatomical Sciences Education*, v. 15, n. 4, p. 719–730, 2022.

https://doi.org/10.5380/avs.v30i2.98315