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Anatomical Reproducibility in Neuroanatomy Using Self-Curing Acrylic Resin

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ABSTRACT
Introduction: neuroanatomy is a branch of Anatomy that seeks to understand the structures of the nervous system. Due to the difficulty of obtaining cadaveric specimens, as well as students' challenges in comprehending anatomical content, it has become necessary to use an innovative method: the creation and use of didactic models. Thus, this study aimed to develop didactic neuroanatomy models using self-curing acrylic resin for teaching human neuroanatomy.
Methods: synthetic models of cerebral hemispheres and brainstem present in the Anatomy Laboratory at the Federal University of Pernambuco were used. These models served to create anatomical molds with alginate. After the alginate mold was made, it was filled with self-curing acrylic resin. Once the resin cooled, the produced models were sent for finishing, painting, and waterproofing.
Results: resin models representing the cerebral hemispheres and brainstem were obtained, allowing the identification of the main structures of each neuroanatomical segment through the use of varied colors for the structures.
Conclusion: through modeling with self-curing acrylic resin, it is possible to reproduce important neuroanatomical structures for the teaching/learning process of human anatomy, providing accurate and didactic representation of structures belonging to regions of the central nervous system.
Keywords: Anatomical Models; Neuroanatomy; Acrylic Resin; Teaching.

Introduction

Human anatomy is a science that seeks to understand the human body as a whole, as well as its constituent organs and structures. It is one of the oldest sciences in the health field.[1,2]Anatomical knowledge about the human body and its particularities serves as a structural foundation for other health-related disciplines, such as Physiology, Pathology, and Semiotics, as well as for clinical practice.[3]

In most undergraduate programs, human anatomy is traditionally taught through lectures given by professors and dissection labs, which have become increasingly scarce in recent years, primarily due to the lack of cadaveric material.[4,5] This growing shortage of cadaveric material in practical anatomy classes results in significant educational losses for students. Many higher education institutions (HEIs) are addressing this gap by incorporating new teaching methodologies that make students active participants in the learning process. These methodologies include the use of mobile and computer applications, body painting techniques, commercial anatomical models, and the students' own creation of these models.[6,7]

The use of didactic models is an innovative and alternative method that can be employed, as these are anatomical models represented by three-dimensional or semi-flat, colored structures that facilitate the teaching and learning process. Consequently, didactic models are becoming a new methodology for teaching anatomy.[8] At different educational levels, these didactic models are used to complement written content and the flat images in textbooks and atlases, which are often colorless and fail to engage students.[9]

Orlando *et al.* (2009)[10] assert that, in addition to their visual presentation, didactic models can be manipulated by students, allowing them to view the models from various angles and thereby improving their understanding of the content. Thus, new didactic tools provide a wide range of concrete and more meaningful possibilities for students, encompassing action and reflection in the learning process and promoting a fundamental shift in the educational paradigm, especially in traditional teaching methodologies.[11]

Due to the scarcity of cadaveric specimens for teaching neuroanatomy at the Life Sciences Center (NCV) of the Federal University of Pernambuco (UFPE), this study developed a new methodology for creating handcrafted neuroanatomy models that could be used in practical human anatomy classes.

Materials and Methods

The present study was conducted in the Anatomy Laboratory of the Life Sciences Center (NCV) at the Agreste Academic Center (CAA) of the Federal

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University of Pernambuco (UFPE). The first step in creating the didactic models was obtaining anatomical molds to be used in the production of resin pieces. Molds were made using Alginate for impressions with Type II Normal Set Chlorhexidine (Dentsply Sirona - Charlotte, USA), a gel-like material commonly used in dental offices for producing prosthetics. The Alginate (in the proportion of 200g for every 200ml of water) was diluted in cold water and mixed for a few seconds until a homogeneous, pasty consistency was achieved. This process must be quick, as the active Alginate dries and hardens quickly.

After mixing, the material was poured into a mold or plastic container, and the synthetic model (classic brain, 5 pieces - 3B Scientific - Hamburg, Germany) (Figure 1) available in the laboratory was immersed in the still pasty Alginate solution to obtain the desired mold shape (Figure 2). Once dried, the synthetic model was removed, and the Alginate molds were filled with Self-Curing Acrylic Resin Type II Class I - Vipi Flash Clear (Vipi Flash - São Paulo, Brazil).

Figure 1. Classic brain, 5 pieces - 3B Scientific.

Figure 2. Application of the anatomical model for alginate modeling.

The resin was diluted in a specific solvent, the self-curing acrylic liquid (Vipi Flash - São Paulo, Brazil), in the proportion of 2 parts resin powder to 1 part liquid (e.g., 14g of powder to 7ml of liquid), following the manufacturer's instructions. The mixture of resin and self-curing liquid was poured into the Alginate mold until completely filled to take the shape of the desired mold. This procedure must be performed slowly and gradually to avoid air bubbles inside the resin. After about an hour, with the resin completely dry and rigid, the anatomical models were removed from the Alginate mold (Figure 3). This methodology followed the procedures described by Caiaffo *et al.* (2021).[12] Next, the resin models were finished by smoothing edges, protrusions, and burrs using sandpaper (waterproof sandpaper for polishing - 3M), utility knives, and a rotary tool (Black Decker RT18KA). After completing the finishing and polishing stage, the main anatomical structures were highlighted with different colored acrylic gouache paints (Tempera Guache, Acrilex) to facilitate visualization. Finally, the anatomical models were coated with a layer of clear varnish (wood varnish - Iquine) to ensure durability and waterproofing of the produced model.

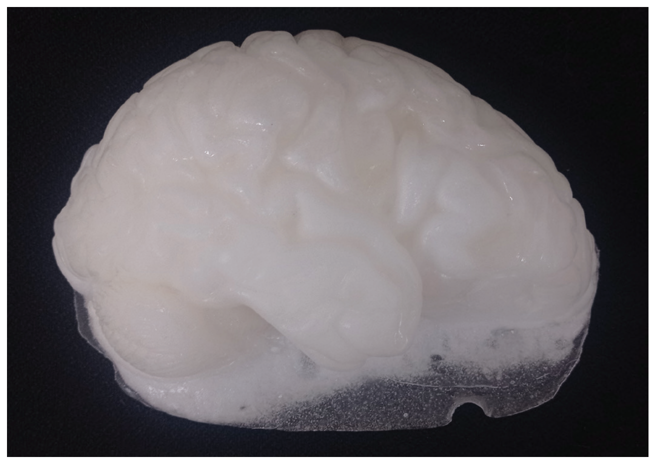

Figure 3. Raw resin model after removal from the alginate mold.

Results

The present study successfully crafted neuroanatomical models of the cerebral hemispheres, depicting the cerebral hemispheres in a midsagittal section. With the use of varied colors in painting, it was possible to identify the main telencephalic lobes on the superolateral surface of the telencephalon: frontal (red), parietal (yellow), occipital (green), and temporal (blue), in addition to a small segment of the cerebellar hemisphere (brown) (Figure 4).

In another model, also using varied colors, the main gyri on the superolateral surface of the telencephalon were reproduced and identified: the precentral gyrus (red), superior frontal gyrus (black), middle frontal gyrus (yellow), inferior frontal gyrus and its subdivisions - opercular (black), triangular (blue), and orbital (green); the postcentral gyrus (blue), superior parietal lobule (orange), inferior parietal lobule (gray), supramarginal gyrus (red), and angular gyrus (brown); the occipital gyri (green); and the superior temporal gyrus (green), middle temporal gyrus (yellow), and inferior temporal gyrus (red) (Figure 5).

Figure 4. Superolateral surface of the telencephalon and its lobar division. Frontal Lobe: red color; Parietal lobe: yellow color; Occipital Lobe: green color; Temporal Lobe: blue color; Cerebellum: brown color.

Figure 5. Superolateral aspect of the telencephalon and its lobar division into gyri or convolutions. Frontal Lobe: Pre-Central Gyrus (red color), Superior Frontal Gyrus (black color), Middle Frontal Gyrus (yellow color), Inferior Frontal Gyrus and its division into Opercular (black color), Triangular (blue color) and Orbital (color green); Parietal Lobe - Post-Central Gyrus (blue color), Superior Parietal Lobe (orange color), Inferior Parietal Lobe (gray color), Supramarginal Gyrus (red color) and Angular Gyrus (brown color); Occipital Lobe - Occipital Gyri (green color); Temporal Lobe - Superior Temporal Gyrus (green color), Middle Temporal Gyrus (yellow color) and Inferior Temporal Gyrus (red color).

Figure 6. Inferior surface of the telencephalon and its division into m gyri or convolutions. Orbital Gyrus (orange color), Rectus Gyrus (brown color), Parahippocampal Gyrus (gray color), Uncus (yellow color), Lateral Occipto-Temporal Gyrus (blue color). And it was also possible to identify a segment of the cerebellar hemisphere (brown color).

On the inferior surface of the telencephalon, the following gyri were identified: orbital gyri (orange), straight gyrus (brown), parahippocampal gyrus (gray), uncus (yellow), and lateral occipitotemporal gyrus (blue). Additionally, a segment of the cerebellar hemisphere (brown) was identified (Figure 6).

Discussion

It is important to note that maintaining a cadaveric collection in higher education institutions incurs complex and high costs for proper utilization and maintenance. Additionally, there are significant challenges associated with acquiring and obtaining cadavers for donation to institutions that use them for teaching human anatomy. Synthetic anatomical models have proven to be a viable alternative to this issue. More recently, these models have been supplemented with multimedia approaches, including radiological images and virtual reality models.[13,14,15] However, the cost of anatomical models, depending on the structures and the level of detail required for better learning of the curricular content, can also be high.

Breaking this paradigm, anatomical reproducibility using self-curing acrylic resin has proven to be a financially feasible alternative. This is particularly important in the context of active learning methodologies, where students become active participants in their learning process through debates and practices that encourage teamwork, rather than passively watching instructors.[16]

Alternatives to the use of cadaveric specimens are not new, as the use of such specimens involves barriers that are often difficult to overcome. Therefore, it is essential that the reproducibility of synthetic pieces is accessible, durable, and faithful to the original specimens.[1,2]

The study of neurosciences necessarily involves the study of neural anatomy. Due to the great complexity of these structures and the lack of effective teaching methods, a 'neurophobia' can develop among students, a stigma prevalent in many students regarding neurosciences. Thus, it is crucial to have models that faithfully replace cadaveric specimens to aid in the study of anatomy and reduce the stigma associated with neurosciences.[1,2]

The reproduction of anatomical pieces using clay and plaster is well-documented, with good reproducibility and quality of definition.[3,4] However, improper and/or excessive handling of these pieces can cause irreparable damage, compromising their integrity, especially when the goal is to use them for teaching large groups of students over many years. On the other hand, the material used in this study, self-curing acrylic resin, though having a higher cost compared to plaster, offers much greater durability and resistance to damage from falls and improper handling.[5,6]

According to Pujol *et al.* (2016)[17], due to budget cuts for cadaveric specimens, there is an urgent need to develop complementary methods that maintain the same level of learning for students concerning the morphofunctional aspects of the human body. Among the strategies implemented to mitigate structural and financial challenges, Azer and Azer (2016)[18] describe that three-dimensional anatomical models, both physical and digital, are highly favored by students in health-related courses, demonstrating their applicability for analyzing anatomical structures. In this context, Kong *et al.* (2016)[19] indicate that 3D models are of great relevance for medical undergraduates, given the positive evaluations from students regarding their use in studying hepatic anatomy. Additionally, these implemented 3D models have practical applications due to their positive characteristics related to conservation, availability, and good student acceptance, making them an advantageous alternative for higher education institutions.[20]

Currently, research is being conducted to understand the advantages of developing specimens using self-curing acrylic resin, with positive points being noted in terms of durability, low costs, and good clarity of anatomical structures.[21] From this perspective, we observe similar benefits to those indicated by Carvalho, Junior, and Esteves (2016)[21], considering that the anatomical models developed for the field of neuroanatomy present advantages related to good durability and impact resistance. It is also pertinent to note that the produced models maintained the contour and details of the original pieces used as a base. The use of different colors for better didactic understanding by students is also highlighted.

Conclusion

In summary, it is concluded that the development of anatomical pieces constructed using self-curing acrylic resin for didactic anatomical models used in neuroanatomy education is highly relevant for the learning of students in educational institutions, especially given budgetary limitations and the scarcity of cadavers for dissection. These representations, beyond being supplementary items for the study of neuroanatomy, have significant advantages for the consolidation of curricular content. Throughout the production process, there was a need to create specimens with realistic representations of the regions within the encephalic framework to ensure effective student learning. Therefore, these pieces can be effectively applied in the teaching-learning process as a fundamental means for the development of essential skills and attitudes in the study of anatomy.

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Mini Curriculum and Author's Contribution

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