







The development of a didactic model to facilitate the understanding of the components and anatomical relations of the middle ear

O desenvolvimento de um modelo didático para facilitar a compreensão dos componentes e das relações anatômicas da orelha média

El desarrollo de un modelo didáctico para facilitar la comprensión de los componentes y relaciones anatómicas del oído medio

Rodrigo Rodrigues da Costa Gomes¹, Monique Evelyn Venturin¹, Gabriel Schorr¹, Rodrigo Bianchi Zancanaro¹, Lígia Aline Centenaro¹, Aline Barbosa Macedo¹

ABSTRACT

The middle ear is important from an anatomical and clinical point of view, seeing that it contains and allows the passages of structures, in addition to establishing relations with other regions of the head. However, the middle ear is small and difficult to dissect, making difficult the study in cadavers and understanding. In this context, professors and students from Universidade Estadual do Oeste do Paraná developed an anatomical model of the middle ear, showing its main bones, membranes, muscles and nerves. The model was developed with acrylic plates joined to form a cube, each side representing one of the middle ear's walls. The tympanic membrane and the secondary tympanic membrane were represented by an elastic fabric, which covered openings on the membranous wall and the labyrinthic wall, respectively. The auditory ossicles, the muscles and the nerves were made from polymer clay and positioned inside the cube, according to their characteristics and anatomical position in the middle ear. Furthermore, the auditory tube was represented by a plastic cone projecting from the carotid wall. The use of these low-cost anatomical models is an alternative to enable and improve learning. These initiatives favor the teaching of Human Anatomy, increasing understanding, the establishment of clinical correlations, and improving the academic education of health professionals.

Keywords: Anatomic models, Medical education, Anatomy teaching.

RESUMO

A orelha média é importante do ponto de vista anatômico e clínico, pois contém e permite a passagem de estruturas, além de estabelecer relações com outras regiões da cabeça. Porém, a orelha média é pequena e dissecação, o que dificulta seu estudo em cadáveres e a compreensão por parte dos alunos. Nesse contexto, docentes e discentes da Universidade Estadual do Oeste do Paraná desenvolveram um modelo anatômico da cavidade timpânica, apresentando seus principais componentes membranáceos, ósseos, musculares e nervosos. Para a confecção da maquete, placas de acrílico transparente foram unidas formando um cubo, com cada placa representando uma das paredes da cavidade timpânica (exceto a parede tegmental). Tecidos elásticos foram colocados em orifícios feitos nas paredes membranácea e labiríntica para representação da membrana timpânica e da membrana timpânica secundária, respectivamente. Os ossículos da audição, músculos e nervos foram confeccionados em biscuit e posicionados no espaço interno do cubo, observando-se as características e a posição anatômica dessas estruturas na orelha média. A tuba auditiva foi representada pela colocação de um cone plástico projetando-se a partir da parede carótica. A confecção de modelos didáticos é uma alternativa de baixo custo para facilitar o ensino e a compreensão da Anatomia Humana. O aprendizado de conceitos básicos favorece o entendimento das correlações anatomoclínicas, melhorando a formação acadêmica dos profissionais de saúde.

Palavras-chave: Modelos anatômicos, Educação, Ensino.

1. Universidade Estadual do Oeste do Paraná. Centro de Ciências Médicas e Farmacêuticas, (PR), Brasil



INTRODUCTION

The middle ear is a small and irregular air-filled cavity located in the petrous part of the temporal bone^{1,2}. This cavity is delimited by six walls, named tegmental, jugular, carotid, mastoid, membranous and labyrinthine³. More specifically, the tegmental wall receives such designation because it is formed by the tegmen tympani, a thin bony plate between the middle ear and the middle cranial fossa. The jugular wall is located inferiorly, separating the middle ear from the internal jugular vein⁴. The carotid wall is anterior and closely related to the carotid canal. This wall is characterized by the presence of the musculotubal canal, a double canal for the auditory tube superiorly and the tensor tympani muscle inferiorly⁵. The mastoid wall is posterior and has an opening called the aditus to the mastoid antrum, which connects the epitympanic recess to the mastoid antrum³. The membranous wall is lateral, constituted by the tympanic membrane and the epitympanic recess' lateral wall¹. Finally, the labyrinthine wall is medial, separating the middle ear from the inner ear. This wall is characterized by two openings: the uppermost is called the oval window, fenestra vestibuli or fenestra ovalis, and the lowermost opening is the round window, fenestra cochlea or fenestra rotunda. The oval window is occupied by the stapes' base and the round window is closed by the secondary tympanic membrane. Between each opening, there is the promontory, a prominence created by the cochlea's base².

The middle ear contains three ossicles: the malleus, the incus and the stapes. The ossicles articulate among themselves, allowing the vibrations produced by sound waves on the tympanic membrane be transmitted to the vestibule's perilymph in the inner ear⁶. The malleus is the most lateral of the ossicles, attached to the umbo of the tympanic membrane by its handle. The medial part of the malleus' handle is also the tensor tympani muscle insertion, allowing it to apply tension to the tympanic membrane and reducing the amplitude of its oscillations⁷. The malleus' head projects to the epitympanic recess, the most superior portion of the middle ear, where it articulates with the incus' body. The incus has two processes: a short one, connected to the mastoid wall by a ligament, and a long one, which at its lower end forms the lenticular process. In fact, the lenticular process is the point where the incus articulates with the stapes' head. The stapes, in turn, is the smallest and most medial of the ossicles. It has a head, neck, anterior process, posterior process, and base. The stapedius muscle fixes to the stapes' neck and its contraction resists excessive movement of this ossicle. The stapes' base inserts itself into the oval window⁴.

Since the middle ear is an intraosseous region made up of millimeter parts, it is difficult to dissect its constituents. Due to this, the practical study of this region is often carried out in isolated anatomical specimens, making it even more difficult to understand the complex three-dimensional relationships of this region⁸. In order to facilitate the learning process, colorful, three-dimensional or high-relief didactic models have been used, because these materials allow manipulation and visualization from multiple angles, improving the concepts presented in the classroom and the two-dimensional images from textbooks⁹⁻¹⁰. Teaching becomes more efficient when students interact with multiple methods of knowledge processing¹¹. Thus, the use of complementary tools increases the efficiency of the teaching and learning process¹². In this sense, this study aimed to create a didactic model of the middle ear to facilitate students' understanding of the anatomical characteristics of this complex region.

METHODS

This project was performed at the Human Anatomy Laboratory at the Universidade Estadual do Oeste do Paraná. Six undergraduate students developed the anatomical model, oriented by two professors. Meetings were performed weekly for design, material choice and to resolve issues.

Initially, the students made auditory ossicles according to images available in human anatomy books¹³⁻¹⁴. Each ossicle was molded from polymer clay, then painted with beige to resemble the bones in the Anatomy lab. After carrying out tests with wooden boards, it was chosen to use acrylic plates to make the middle ear's walls. More specifically, the membranous wall of the middle ear was made from two thin acrylic plates with a large opening, which was covered by a white elastic fabric representing the tympanic membrane. For the labyrinthine wall, two other thin acrylic plates with two smaller openings were used. The uppermost opening was elliptical and represented the oval window, while the lower opening was circular and represented the round window. A white elastic tissue was positioned between the two plates at the level of the round window to represent the secondary tympanic membrane. The carotid wall was made from a thicker acrylic plate, with a small circular opening at the top. A plastic cone, painted white, was connected to this opening to represent the auditory tube. Two thickest plates were used to represent mastoid and jugular walls, with no openings.

Finally, a rectangular piece of polyethylene terephthalate (PET) was attached to the superior part of the box to form a dome, representing the tegmental wall.

The walls were bonded with instant glue to form the cube as follows: the membranous wall opposite the labyrinthine wall; the carotid wall opposite the mastoid wall; the jugular wall forming the base and the tegmental wall closing the top of the cube. In order to facilitate comprehension, each side of the cube was identified with the name of the middle ear walls and their anatomical position.

The ossicles were positioned in the central space of the cube using nylon wires, according to the anatomical position of these structures within the middle ear. The handle of the malleus was attached to the center of the fabric that represented the tympanic membrane, forming a convexity toward the center of the cube. The head of the malleus and the incus body were kept in the center and above the cube's top edge, indicating that these bone parts project to the epitympanic recess. Lastly, the stapes base was placed into the elliptical opening present in the labyrinthine wall, representing the junction of this bone part in the oval window.

After the ossicles were in place in the cube, the stapedius muscle and the tensor tympani muscle were molded with polymer clay.

Their bellies were painted red and the tendon painted white. The pyramidal eminence, a small bony protuberance, was also made. All these components were put into the cube according to the anatomical position.

A plastic tube of approximately 19 cm in length and 0.8 cm in diameter was cut in half and colored beige, the same tone used for all skeletal structures, in order to represent the facial canal. The facial nerve was molded in yellow polymer clay and placed inside this plastic tube. Afterward, this facial canal was pasted into the mastoid wall so that the facial nerve could be visualized on the outer side of the cube, while in the inner space of the cube, only the facial canal was apparent. The chorda tympani nerve, a branch of the facial nerve, was molded and positioned emerging from the facial canal inside the cube. The tympanic plexus was represented by several fillets made of yellow polymer clay, which were glued to half of a beige-painted Styrofoam sphere. Finally, this sphere was placed in the labyrinthine wall, with their convexity turned to the center of the cube, representing the promontory.

RESULTS AND DISCUSSION

Anatomical models are commonly used in Human Anatomy classes to facilitate and improve learning. However, the commercial anatomical models are costly and, in some cases, lacking in details. Thus, this work aimed to develop an anatomic model with a more accessible cost and adequate detail of the middle ear's structures.

The middle ear anatomical model was developed on a larger scale to facilitate the visualization of the constituents and this topographic disposition (Fig. 1A-E). The handle of the malleus was attached to the fabric that represented the tympanic membrane in such a way that it creates an outward concavity (representing the umbo) and an inward convexity (toward the tympanic cavity) (Fig. 1A-C). This disposition corresponds to the tympanic membrane's orientation in humans, which resembles a "parabolic antenna". Such representation also allows students to understand that the movement created by sound waves on the tympanic membrane is converted to mechanical vibration on the malleus¹. The ovoid end of the incus, called the lenticular process, was adjusted to articulate with the head of stapes (Fig. 1D). The base of stapes, in turn, was positioned in the oval window on the labyrinthine wall (Fig. 1B). Thus, the model presents a faithful representation of the articulations between the ossicles of the middle ear, helping the students to understand that the malleus' vibrations are transmitted to the subsequent ossicles and create hydraulic pressure waves in the vestibule's perilymph¹⁵.

The origins and insertions of the muscles related to the middle ear's ossicles were also represented according to their descriptions in the literature. The tensor tympani muscle was positioned from the carotid wall (just above the auditory tube) to its fixation on the malleus handle (Fig. 1C,E). The pyramidal eminence, a protrusion that contains the stapedius muscle, was molded on the mastoid wall. The tendon of the stapedius muscle, in turn, was fixed to the neck of the stapes bone¹ (Fig. 1D-E).

Knowledge of the middle ear anatomy is indispensable in surgeries such as ossiculoplasties and tympanoplasties, which aim to reestablish the tympanic membrane and the ossicle chain using synthetic prostheses or bone grafts¹⁹⁻²⁰.

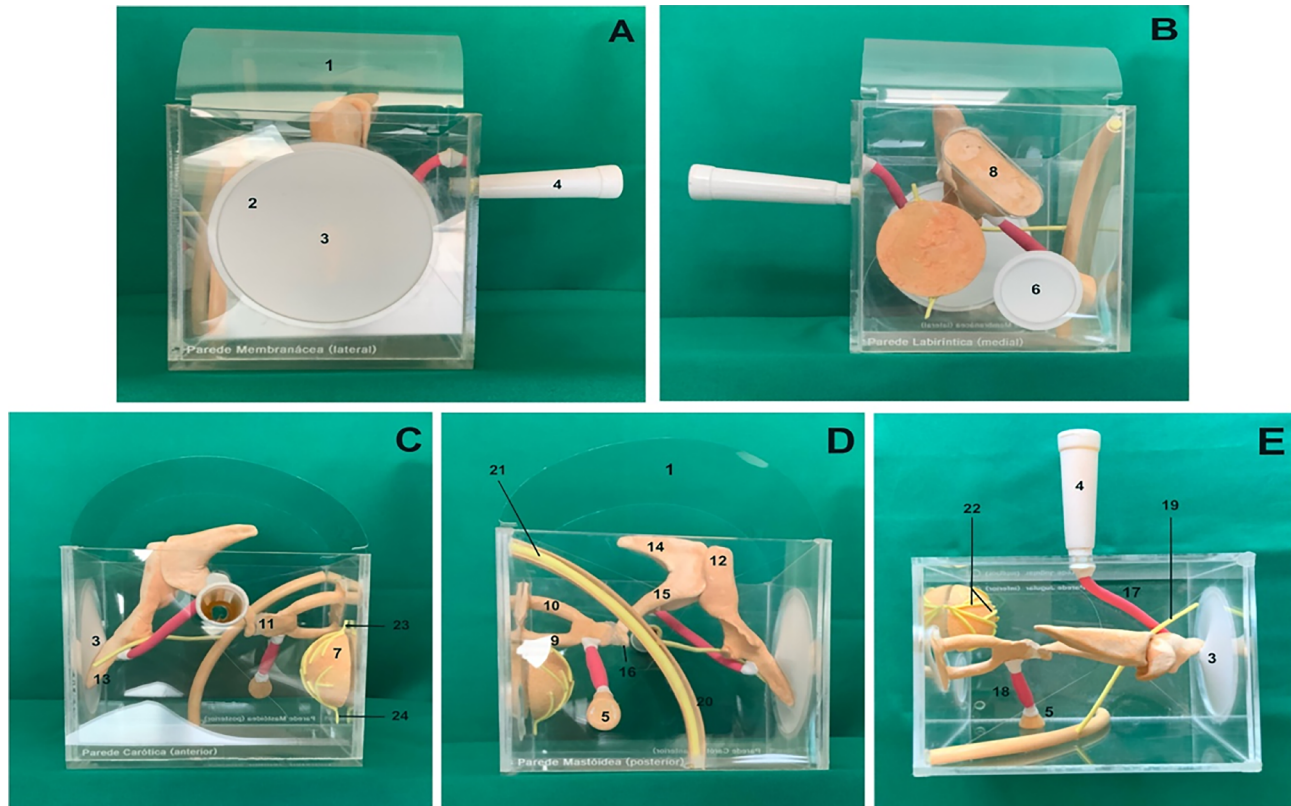


Figure 1. Anatomical model of the middle ear in different views. **A** Membranous wall (lateral). **B** Labyrinthine wall (medial). **C** Carotid wall (anterior). **D** Mastoid wall. **E** Superior view with the tegmental wall removed. Numbers represent: ¹Epitympanic recess and tegmental wall; ²Tympanic membrane; ³Umbo of the tympanic membrane; ⁴Auditory tube; ⁵Pyramidal eminence; ⁶Round window sealed by the secondary tympanic membrane; ⁷Promontory; ⁸Base of stapes; ⁹Posterior process of stapes; ¹⁰Anterior process of stapes; ¹¹Head of stapes; ¹²Head of malleus; ¹³Handle of malleus; ¹⁴Short process of incus; ¹⁵Long process of incus; ¹⁶Lenticular process; ¹⁷Tensor tympani muscle; ¹⁸Stapedius muscle; ¹⁹Tympani Chorda nerve; ²⁰Facial nerve canal; ²¹Facial nerve; ²²Tympanic plexus on the promontory; ²³Lesser petrosal nerve; ²⁴Tympanic nerve.

The refinement of the sculpture of the ossicle prostheses, making them more similar to normal anatomy, is a decisive factor in relation to the success of these surgeries¹⁹. Such procedures are used to restore hearing in individuals with trauma, infection, cancer, or congenital disorders²⁰.

Concerning the nervous structures, in the anatomical model proposed, the tympani chorda nerve was molded from the facial nerve as it passed in the facial nerve canal (Fig. 1E). The tympanic plexus was positioned over the mold for the promontory, which was affixed to the labyrinthine wall (Fig. 1E). One of the nerves derived from the plexus, the lesser petrosal nerve, was represented by a single strand extending above the promontory (Fig. 1C). The tympanic nerve, a branch of the glossopharyngeal nerve which gives origin to the plexus itself, was represented by another strand extending downwards of the promontory (Fig. 1C).

It is important that medical students understand the topographic relationships between the middle ear and structures such as the facial nerve, the internal carotid artery and the internal jugular vein⁴. For example, an intrapetrous internal carotid aneurysm can produce hearing and vestibular disturbances, such as tinnitus, hypoacusis and vertigo¹⁶⁻¹⁷. In rare cases, this type of aneurysm can also cause compress the facial nerve, resulting in paralysis of the areas innervated by this nerve¹⁶. The anatomical relationships between these structures must be considered during surgeries to treat dissecting aneurysms, which involve exposing the petrous part of the internal carotid artery, so that the middle ear's other structures be adequately protected¹⁸.

Finally, it is important to point out that using anatomical models allows the student to observe small and intricate structures on a larger scale, favoring understanding during the visualization of cadaveric pieces²¹.

In addition, developing these models not only helps to learn during classes but also improves the understanding of students who participate in their elaboration²². Thus, the use of three-dimensional anatomical models can make teaching more attractive compared to traditional pedagogy, encouraging students to learn more actively⁹⁻¹².

CONCLUSIONS

Considering the complexity of teaching Human Anatomy, its comprehension may become difficult, especially regarding small structures which are hard to access by dissection, as is the case of the middle ear. Therefore, the inclusion of didactic tools might facilitate students' understanding and make studying more attractive. The anatomic model of the middle ear, assembled with attention to details, following the literature, can be considered a means to favor the study, improving the training of health professionals and favoring the future development of new therapies.

REFERENCES

- Moore KL. Anatomia orientada para a clínica. 7. ed. Rio de Janeiro: Koogan; 2014. p. 1159-1174.
- Gray H; Goss CM. Anatomia. 29. ed. Rio de Janeiro: Guanabara; 1988. p. 881-884.
- Dangelo JG; Fattini CA. Anatomia humana sistêmica e segmentar. 3. ed. São Paulo: Atheneu; 2007. p. 533-534.
- Standring S, editora. Gray's Anatomia. Rodrigues D, tradutor. 40. ed. Rio de Janeiro: Elsevier. 2010. p. 623-628
- Drake RL; Vogl W; Mitchell AWM. Gray's, anatomia para estudantes. Varga V, et al., tradutores. 3. ed. Rio de Janeiro: Elsevier. 2015. p. 906-910.
- Alberti, PW. The anatomy and physiology of the ear and hearing. In B. Goelzer, C. H. Hansen, & G. A. Sehrndt, editores, Occupational exposure to noise: Evaluation, prevention and control. Bremerhaven, Germany: World Health Organization. 2001. p. 53-62.
- Spence AP. Anatomia humana básica. Liberti, E. A. (tradutor). 2. ed. São Paulo: Manole. 1991. p. 471.
- Ng CL, Liu X, Chee SCJ, Ngo RYS. An innovative 3-dimensional model of the epitympanum for teaching of middle ear anatomy. *Otolaryngol - Head Neck Surg (United States)*. 2015;153(5):832-7.
- Azer SA, Azer S. 3D Anatomy models and impact on learning: a review of the quality of the literature. *Heal Prof Educ [Internet]*. 2016;2(2):80-98. Available from: <http://dx.doi.org/10.1016/j.hpe.2016.05.002>
- Peixoto P, De Medeiros Garcia ARS, Bissoli NS, Ramos ACS. Benefits of a memory game as a didactic strategy in the learning of human physiology. *Mundo Saúde, São Paulo*. 2018;42(2):316-32.
- Mota MF, Da Mata FR, Aversi-Ferreira TA. Constructivist pedagogic method used in the teaching of human anatomy. *Int J Morphol*. 2010;28(2):369-74.
- Orlando TC, Lima AR, Da Silva AM, Fuzissaki CN, Ramos CL, Machado D, et al. Planejamento, montagem e aplicação de modelos didáticos para abordagem de biologia celular e molecular no ensino médio por graduandos de ciências biológicas. *Rev Ensino Bioquímica*. 2009;7(1):1.
- Netter FH. Atlas de Anatomia Humana. 4. ed. Rio de Janeiro: Elsevier. 2008.
- Putz R, Pabst R. Sobotta: Atlas de Anatomia. 20. ed. Rio de Janeiro: Guanabara Koogan. 1993; v. 1.
- Hall JE. Tratado de Fisiologia Médica. 12. ed. Rio de Janeiro: Elsevier. 2011. p. 671.
- Brandt TW, Jenkins HA, Coker NJ. Facial paralysis as the initial presentation of an internal carotid artery aneurysm. *Arch Otolaryngol Neck Surg*. 1986;112(2):198-202.
- Rogano LAC, Cavalheiro S, De Tella OI Júnior, Braga FM. Aneurisma gigante da carótida interna na porção petrosa. *J. Bras. Neuroc*. 1990; 2(1):14-20.
- Paullus WS, Pait TG, Rhoton AL. Microsurgical exposure of the petrous portion of the carotid artery. *J Neurosurg*. 1977;47(5):713-26.
- McGee, M., Hough, J.V.D. (1999). Ossiculoplasty. *Otolaryngologic clinics of North America*. 1999; 32(3), 471-488.
- Samy, Ravi N., Pensak, Myles L. Revision Ossiculoplasty. *Otolaryngologic clinics of North America*. 2006; 39(4), 699-712.
- Dos Santos ERS, Da Silva JJ, De Melo ALFD, Ferreira MBS, Brito VC. Anatomia em modelos didáticos: uma nova estratégia educacional. In: Anais do 23th Congresso Internacional de Tecnologia na Educação; 2015 Sep 23-25; Recife, PE, Brasil.
- Hochmuller LHL, Padilha DS, Moraes GG, Pазze EL, Da Silva JPM, Alencar MR. A construção de modelos didáticos no estudo de estruturas microscópicas na disciplina de ciências no ensino fundamental. *MoEduCiTec*. 2017;2.

Contribuições dos autores

Rodrigo Rodrigues da Costa Gomes – Esboço do estudo, redação e revisão do artigo científico; Monique Evelyn Venturin – Esboço do estudo, redação e revisão do artigo científico Gabriel Schorr – Esboço do estudo, redação e revisão do artigo científico; Rodrigo Bianchi Zancanaro – Esboço do estudo, confecção do modelo anatômico e revisão da versão final do artigo científico; Lígia Aline Centenaro - Esboço do estudo, confecção do modelo anatômico, redação e revisão do artigo científico; Aline Barbosa Macedo - Esboço do estudo, confecção do modelo anatômico, redação do artigo científico.

Fontes de financiamento

O estudo foi desenvolvido sem o apoio de fontes de financiamento. Agradecemos a Universidade Estadual do Oeste do Paraná pela infraestrutura concedida para o desenvolvimento deste estudo.

Contribuições dos autores

Os autores agradecem aos técnicos de laboratório José Carlos Cintra e Adélio Ortiz pelo auxílio durante a confecção do modelo anatômico.

Autor Correspondente:

Lígia Aline Centenaro

lacentenaro@hotmail.com / ligia.centenaro@unioeste.br

Editor:

Ada Clarice Gastaldi

Received in: mar 1, 2022

Approved in: may 18, 2022
