DEVELOPMENT AND APPLICATION OF AN ANATOMICAL BIOMODEL FOR TEACHING ORCHIECTOMY IN DOGS

DESENVOLVIMENTO E APLICAÇÃO DE BIOMODELO ANATÔMICO PARA O ENSINO DA ORQUIECTOMIA EM CÃES

DESARROLLO Y APLICACIÓN DE UN BIOMODELO ANATÓMICO PARA LA ENSEÑANZA DE LA ORQUIECTOMÍA EN PERROS

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ABSTRACT
The teaching of veterinary surgery requires strategies that enable the development of technical skills in a safe and ethical manner. In this context, the present study aimed to develop an anatomical biomodel of the male canine genitourinary region for training in the orchiectomy technique, as well as to evaluate its applicability as a didactic tool. The biomodel was constructed using low-cost materials, including biscuit modeling clay for support structures, clear rubber for internal anatomical components, and platinum-cured transparent silicone to simulate the skin layer. After fabrication, the model was subjected to practical testing, in which the fundamental steps of the surgical procedure, such as incision, dissection, and manipulation of anatomical structures, were performed. The results demonstrated that the biomodel presented adequate anatomical fidelity and mechanical properties compatible with surgical simulation, allowing the procedure to be carried out in a safe and reproducible manner. From an educational perspective, the model enabled repeated practice in a controlled environment, contributing to the improvement of practical skills, reduction of errors, and increased student confidence. Furthermore, its use is aligned with the principles of reduction, refinement, and replacement (3Rs), representing an ethical alternative to the use of animals in teaching. It is concluded that the proposed biomodel has strong potential to be incorporated as a complementary tool in veterinary surgical education, contributing to the training of more qualified professionals.

Keywords: Anatomical Biomodels. Orchiectomy. Surgical Training. Teaching Innovation. Veterinary Education.

RESUMO
O ensino da cirurgia veterinária exige estratégias que possibilitem o desenvolvimento de habilidades técnicas de forma segura e ética. Nesse contexto, o presente estudo teve como

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objetivo desenvolver um biomodelo anatômico da região geniturinária de cães machos para o treinamento da técnica de orquiectomia, bem como avaliar sua aplicabilidade como ferramenta didática. O biomodelo foi confeccionado com materiais de baixo custo, incluindo massa de biscuit para estruturas de sustentação, clear rubber para as estruturas internas e silicone transparente à base de platina para simulação da pele. Após a confecção, o modelo foi submetido a testes práticos, nos quais foram realizadas as etapas fundamentais do procedimento cirúrgico, como incisão, dissecção e manipulação das estruturas anatômicas. Os resultados demonstraram que o biomodelo apresentou adequada fidelidade anatômica e propriedades mecânicas compatíveis com a simulação cirúrgica, permitindo a execução do procedimento de forma segura e reprodutível. Do ponto de vista educacional, o modelo possibilitou a repetição das técnicas em ambiente controlado, contribuindo para o aprimoramento das habilidades práticas, redução de erros e aumento da confiança dos estudantes. Além disso, sua utilização está alinhada aos princípios dos 3Rs, configurando-se como alternativa ética ao uso de animais no ensino. Conclui-se que o biomodelo proposto apresenta potencial para ser incorporado como ferramenta complementar no ensino da cirurgia veterinária, contribuindo para a formação de profissionais mais qualificados.

Palavras-chave: Biomodelos Anatômicos. Ensino Veterinário. Inovação Didática. Orquiectomia. Treinamento Cirúrgico.

RESUMEN

La enseñanza de la cirugía veterinaria requiere estrategias que permitan el desarrollo de habilidades técnicas de forma segura y ética. En este contexto, el presente estudio tuvo como objetivo desarrollar un biomodelo anatómico de la región genitourinaria de perros machos para el entrenamiento en la técnica de orquiectomía, así como evaluar su aplicabilidad como herramienta didáctica. El biomodelo se elaboró con materiales de bajo costo, incluyendo masa para galletas para las estructuras de soporte, caucho transparente para las estructuras internas y silicona transparente a base de platino para la simulación de la piel. Tras su construcción, el modelo se sometió a pruebas prácticas, en las que se realizaron los pasos fundamentales del procedimiento quirúrgico, como la incisión, la disección y la manipulación de las estructuras anatómicas. Los resultados demostraron que el biomodelo presentaba una fidelidad anatómica adecuada y propiedades mecánicas compatibles con la simulación quirúrgica, lo que permitió realizar el procedimiento de forma segura y reproducible. Desde un punto de vista educativo, el modelo permitió la repetición de técnicas en un entorno controlado, contribuyendo a la mejora de las habilidades prácticas, la reducción de errores y el aumento de la confianza del alumnado. Además, su uso se alinea con los principios de las 3R, consolidándose como una alternativa ética al uso de animales en la enseñanza. Se concluye que el biomodelo propuesto tiene el potencial de incorporarse como una herramienta complementaria en la formación en cirugía veterinaria, contribuyendo a la capacitación de profesionales más cualificados.

Palabras clave: Biomodelos Anatómicos. Enseñanza Veterinaria. Innovación Didáctica. Orquiectomía. Entrenamiento Quirúrgico.

1 INTRODUCTION

Veterinary Medicine plays an essential role in promoting animal health and welfare, requiring professionals to possess a solid technical background combined with a thorough understanding of the anatomical, physiological, and surgical characteristics of different species. In this context, the teaching of anatomy and surgical techniques represents one of the fundamental pillars of academic training, providing the basis for the development of clinical and operative competencies (Dyce; Sack; Wensing, 2019; Köning; Liebich, 2021).

Traditionally, veterinary anatomy teaching has been based on the use of cadavers and anatomical specimens, allowing direct contact with real structures and enhancing the three-dimensional perception of the organism. However, the acquisition, preservation, and maintenance of these materials present limitations related to specimen availability, operational costs, and sanitary requirements. In addition, preservation methods may alter tissue properties and compromise anatomical fidelity (Carvalho et al., 2013; Evans; De Lahunta, 2018).

At the same time, there is a growing concern regarding the ethical aspects associated with the use of animals for educational purposes. In this scenario, the principles of the 3Rs—reduction, refinement, and replacement—stand out, guiding the development of more ethical and sustainable alternative methodologies (Russell; Burch, 1959; Oliveira; Notomi, 2023; Knight, 2011).

In response to these demands, the incorporation of innovative educational technologies has gained prominence in veterinary education. Among these, the use of artificial anatomical models emerges as a relevant complementary strategy, allowing the reproduction of biological structures through synthetic materials and enabling their repeated use in practical activities. Studies indicate that three-dimensional models contribute to the spatial understanding of anatomical structures and support active learning methodologies (Barros; Schmidt, 2019; Ayres et al., 2020; McGaghie et al., 2010).

Anatomical biomodel can be produced using different materials, such as silicone, resins, and low-cost synthetic compounds, making their application feasible across diverse institutional settings. Their ability to faithfully reproduce organs and anatomical systems enables the development of accessible and adaptable teaching resources. Evidence demonstrates that the use of these models enhances practical learning and contributes to the consolidation of anatomical knowledge (Macedo et al., 2021; Nascimento; Silva, 2021; Santos et al., 2021; Botti et al., 2018).

Beyond anatomical teaching, artificial models have been widely used for the training of surgical skills. Procedures such as orchiectomy in dogs are routine in small animal practice and require technical proficiency and surgical confidence. In this context, prior training in simulated environments allows the development of motor skills, familiarization with procedural steps, and reduction of errors in clinical practice (Slatter, 2020; Toniollo; Vicente, 2017; Seymour et al., 2002).

Studies indicate that the use of anatomical biomodels in surgical training improves technical performance, increases procedural safety, and reduces the occurrence of errors in real interventions. Furthermore, it enables repeated practice and promotes learner autonomy (Silva; Lopes, 2018; Ziegler; Souza, 2021; Issenberg et al., 2005).

Thus, the use of biomodels represents a viable educational tool aligned with contemporary demands in veterinary training, contributing to pedagogical innovation, adherence to ethical principles, and the improvement of practical skills.

In light of the above, the present study aimed to develop an anatomical biomodel of the male canine genitourinary region for training in the orchiectomy technique, as well as to evaluate its applicability as a didactic tool in veterinary surgical education. Additionally, it sought to contribute to the preparation of students prior to performing procedures on real patients, promoting greater safety and reducing errors during the procedure.

2 METHODOLOGY

2.1 STUDY DESIGN

This study was designed as an experimental investigation focused on the development of an anatomical biomodel of the male canine reproductive system, with a didactic and educational purpose. The primary aim was to produce a safe, reproducible, and low-cost anatomical model that could be applied in practical teaching activities for veterinary students, minimizing exposure to hazardous chemicals and enhancing both spatial and tactile understanding of complex anatomical systems.

2.2 MATERIALS

Low-cost and easily accessible materials were used, including biscuit modeling clay for structural modeling, clear rubber for the fabrication of internal anatomical structures, and platinum-cured transparent silicone for simulating the skin layer.

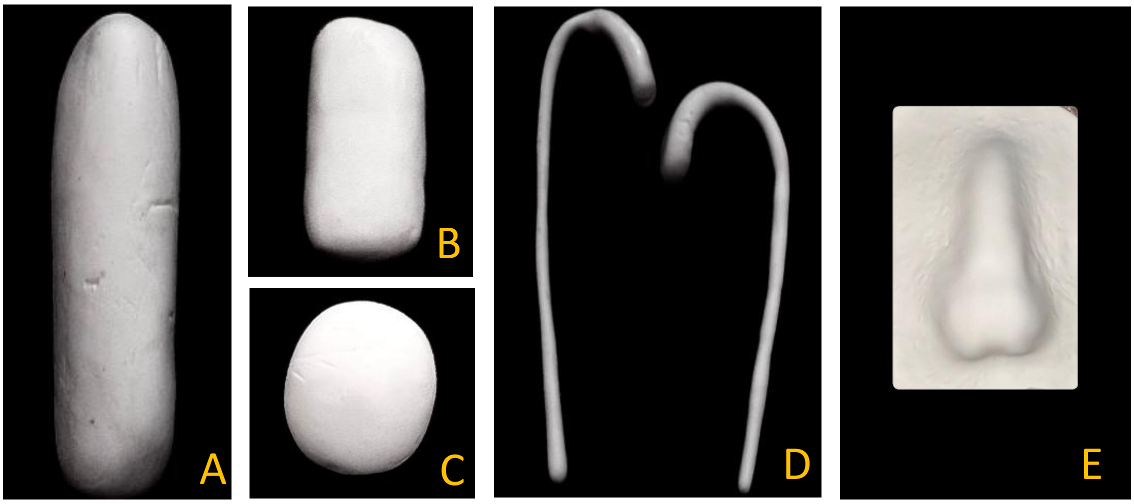
Auxiliary materials included silicone adhesive, wool string, and plastic containers. Personal protective equipment (gloves and lab coat) was used throughout the fabrication process, which was conducted in a controlled environment without direct light exposure or external disturbances to ensure material stability and consistency.

2.3 FABRICATION OF BISCUIT MOLDS

The initial modeling phase consisted of individually constructing the anatomical structures using biscuit material, including two testicles, epididymis, ductus deferens, penis, and a skin layer, in addition to a support structure designed to stabilize the model (Figure 1).

Figure 1

(A) Biscuit structure representing the penis; (B) biscuit structure designed as the support base; (C) biscuit structure representing the testicle; (D) biscuit structure representing the epididymides and ductus deferens; (E) biscuit structure representing the skin



Source: Prepared by the authors.

All components were fixed onto a base to ensure dimensional stability and facilitate handling during subsequent stages. The molds were allowed to dry for four days in a controlled environment, ensuring adequate structural integrity and resistance. Environmental control was essential to preserve anatomical fidelity and mechanical properties required for future didactic application.

2.4 SILICONE MOLDING TEST

After complete hardening of the biscuit structures, one testicle was selected for a preliminary silicone molding test using general-purpose silicone adhesive (Figure 2). This step aimed to evaluate material behavior during curing, determine the required drying time, and identify potential adjustments for subsequent molding procedures.

Figure 2

Testicular mold produced using general-purpose silicone adhesive

Source: Prepared by the authors.

The resulting mold was stored in a protected environment, without exposure to direct light or manual handling, to prevent deformation or contamination. No release agents, oils, or petroleum-based substances were used, allowing direct assessment of the material's performance.

After a three-day curing period, the mold demonstrated satisfactory structural integrity, although minor imperfections were observed. These findings guided refinements in later stages of the fabrication process.

Following validation of this initial test, the remaining anatomical structures were molded using the same technique, ensuring morphological fidelity and structural uniformity. The previously constructed support base was maintained in its original form and was not subjected to silicone molding, as its structural function had already been achieved.

To improve adaptation to internal components and enhance manufacturing control, the skin mold was developed in two separate parts (upper and lower portions). This approach facilitated the accommodation of internal structures (testicles, penis, ductus deferens, epididymis, and support base), allowed better control of material thickness, improved surface finishing, and reduced deformation during curing.

2.5 FINAL FABRICATION OF INTERNAL ANATOMICAL STRUCTURES

After successful mold development, the molds were used to produce the final anatomical structures. This phase aimed to improve morphological precision and ensure uniformity among the components of the anatomical biomodel.

Clear rubber was used as the primary material and carefully introduced into the molds under controlled conditions, respecting curing time and environmental requirements. The structures were maintained in a protected environment without direct light exposure or manipulation until complete curing.

This procedure minimized defects such as deformation and air bubble formation. After curing, the structures were carefully removed from the molds, resulting in satisfactory reproduction of anatomical features and preservation of key morphological characteristics. These results confirmed the effectiveness of the technique for producing didactic anatomical models.

2.6 FABRICATION OF THE SKIN STRUCTURE

For the final stage, the external skin structure of the anatomical biomodel was produced using platinum-cured transparent silicone, composed of two components (A and B) mixed in equal proportions according to the manufacturer's instructions.

An initial pilot test was conducted to evaluate the material's mechanical resistance and suitability for surgical simulation, particularly for suturing procedures. This preliminary step confirmed the material's applicability and allowed identification of potential limitations.

Following validation, the definitive mold was prepared. Components A and B were weighed separately (totaling 152 g) and thoroughly homogenized to ensure uniform curing. The mixture was then poured into the mold designed to represent the external skin layer.

To enhance anatomical definition and ensure consistent thickness, the internal portion of the mold was positioned over the still-fluid silicone. The initial attempt did not fully meet expectations regarding structural quality and surface finish. Therefore, adjustments were made, including improved homogenization of the material and better control of mold assembly to reduce air bubbles.

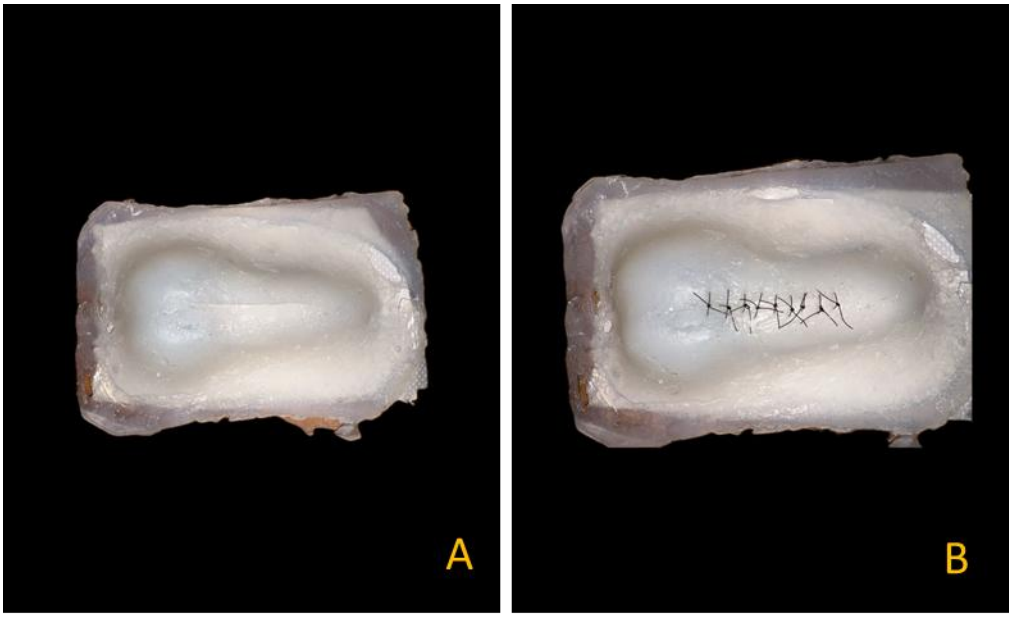
A second fabrication attempt resulted in improved anatomical definition, structural integrity, and mechanical properties compatible with its intended application. The final assembly was allowed to cure for approximately three days in a protected environment, resulting in a structure suitable for integration into the final anatomical model.

2.7 ANATOMICAL BIOMODEL ASSEMBLY AND TESTING

After completion of all components, the full anatomical biomodel of the male canine genitourinary region was assembled and tested in a controlled environment to simulate orchiectomy procedures (Figure 3).

Figure 3

(A) Finalized anatomical biomodel; (B) Appearance of the biomodel after training in the orchiec tomy technique and suturing



Source: Prepared by the authors.

The model was positioned on a flat surface in dorsal recumbency, replicating standard surgical positioning. Basic surgical instruments, including scalpel, anatomical forceps, needle holders, and scissors, were used.

Incisions were performed on the simulated skin layer to replicate surgical access, allowing exposure of internal structures. Subsequent dissection enabled identification of anatomical components such as testicles, epididymis, and ductus deferens.

The exposed structures were manipulated using surgical instruments to simulate tissue handling, isolation, and exteriorization of the testicle. The procedure followed the fundamental steps of canine orchiectomy, including manipulation of the spermatic cord.

Throughout the procedure, standard surgical maneuvers were performed to assess whether the anatomical biomodel allowed adequate reproduction of the technique. The evaluation focused on the feasibility of completing surgical steps, structural resistance, and overall applicability of the model for training purposes

3 RESULTS AND DISCUSSION

The development of the anatomical biomodel of the male canine genitourinary region demonstrated clear technical feasibility and relevant didactic applicability, indicating that the strategic combination of materials was a determining factor in achieving structures with mechanical and morphological properties comparable to biological tissues. This reinforces the importance of material selection in the design of synthetic models intended for surgical training, particularly when the objective includes both structural fidelity and functional simulation.

The use of biscuit as a structural support material proved effective due to its dimensionais stability, ease of handling, and low cost, making it suitable for the initial modeling phase. In contrast, the application of clear rubber for internal anatomical structures provided greater flexibility and improved tactile feedback, which are essential characteristics for simulating tissue manipulation. These findings support the concept that multimaterial approaches enhance the realism of synthetic models by allowing the reproduction of distinct biomechanical properties within the same structure (Barros; Schmidt, 2019).

The transparent silicone rubber used to simulate the skin layer exhibited adequate resistance to incision and manipulation, allowing the execution of surgical maneuvers without immediate structural compromise. The implementation of preliminary testing was a critical step in refining the fabrication process, as it enabled adjustments that improved anatomical definition and overall uniformity. This highlights the relevance of iterative development and process standardization in the production of biomodels, particularly when consistency and reproducibility are required for educational use.

During the surgical simulation phase, the biomodel allowed the execution of the fundamental steps of orchiectomy, including incision, dissection, identification, and manipulation of anatomical structures. Although the model does not fully replicate the complexity of living tissues—such as vascularization, bleeding, and dynamic tissue response—it provided sufficient fidelity to support the acquisition of procedural knowledge and basic technical skills. This observation aligns with previous findings that emphasize the role of simulation in bridging the gap between theoretical learning and clinical practice (Issenberg et al., 2005).

From an educational perspective, the possibility of repeated practice in a controlled and safe environment represents a significant advantage, as it contributes to the progressive development of psychomotor skills, reduction of procedural anxiety, and increased confidence among students. Furthermore, the use of biomodels directly addresses ethical concerns associated with the use of animals in teaching, aligning with the principles of reduction, refinement, and replacement (3Rs), and supporting a shift toward more sustainable and ethically responsible educational practices.

Despite these advantages, some limitations must be considered. The durability of the materials under repeated use remains a critical factor, as progressive degradation may compromise both structural integrity and simulation quality over time. Additionally, the level of anatomical detail, particularly in smaller or more complex structures, may not fully match that observed in biological specimens. These limitations suggest that, while the biomodel is effective as a complementary teaching tool, it does not replace the need for exposure to real anatomical conditions.

Future studies should focus on the incorporation of alternative materials with improved mechanical resistance and greater anatomical fidelity, as well as on the validation of the anatomical biomodel through objective assessment methods involving larger groups of students. Quantitative evaluation of learning outcomes and skill acquisition would further strengthen the evidence supporting its educational effectiveness and facilitate its integration into veterinary curricula.

4 CONCLUSION

The anatomical biomodel of the male canine genitourinary region developed in this study proved to be a viable and effective didactic tool for training in the orchiectomy technique.

The combination of materials used enabled the construction of a model with adequate anatomical fidelity and mechanical properties compatible with surgical simulation, allowing the main steps of the procedure to be performed in a safe and reproducible manner.

From an educational perspective, the anatomical biomodel contributes to the improvement of students' technical skills, promoting practical learning in a controlled environment, with reduced errors and increased confidence during the execution of surgical procedures.

Furthermore, its use is aligned with the principles of reduction, refinement, and replacement (3Rs), representing an ethical and accessible alternative to the use of animals in teaching.

Thus, the proposed anatomical biomodel demonstrates strong potential to be incorporated as a complementary tool in veterinary surgical education, contributing to the training of more qualified professionals and to the advancement of innovative pedagogical practices.

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