ANALYSIS OF MECHANICAL PROPERTIES OF SPAYED CANINE LUMBAR VERTEBRAE

Ernest Kostenko (1), Rimantas Stonkus (2), Algirdas Maknickas (3)

1,3. Department of Biomechanical Engineering, Vilnius Gediminas Technical University, Lithuania; 2. Department of Mechatronics and Robotics and Mechanical Engineering, Vilnius Gediminas Technical University, Lithuania

Introduction

One of the main functions of the spine is to protect the spinal cord; another is to distribute weight while the body is walking, running, or even standing [1]. When the function or mechanical properties of the spine are impaired, disease occurs [2]. One disease of the spine is osteoporosis. Seeking to combat spinal diseases, including osteoporosis, biomechanical engineers and surgeons work together to explore properties of the spine and improve or discover new treatments. [3]

The aim of the current research was to investigate experimentally the mechanical properties of each vertebra in a spayed female eight-year-old dog (bitch).

Methods

For our analysis, we used a spayed female mongrel dog that was approximately eight years old and weighed 28 kg. The dog had been euthanized in accordance with good veterinary practice following diagnosis of a mammary gland tumor. After euthanasia, an autopsy was performed. During the autopsy, the lumbar segment was removed and subsequently stored in the freezer at -20 °C until testing. The day before the test, the segment was removed from the freezer and thawed gradually in saline. When the lumbar section was completely thawed, the muscles and tissues were removed, and the vertebrae were separated. During this process, the vertebrae were kept moist.

a) b)

Figure 1: a) Spayed dog vertebras (Th11-L5) b) Mecmesin MultiTest 2,5-i microcompression machine.

The compression tests were performed using a Mecmesin MultiTest 2,5-i microcompression machine (Mecmesin Limited, Slinfold, UK). The Mecmesin AFG25 load cell had a controlled load of measured accuracy at ±0.01 mm, and it exerted a compression force in the range of 2–2500 with accuracy at ±0.1% where crosshead speed accuracy was ±0.1%. Each vertebra (Figure 1a) was compressed with a force of 950 N. The velocity was chosen equal to 1 mm/min. The vertebrae were adjusted for cyclic loads and selected to work for 10 cycles. After the experiment, the axis of each vertebra was measured. After installing a sample, cyclic loading was applied (Figure 1b).

Results

Comparison of experimental and theoretical data obtained in the first load/unload cycle are presented in Figure 2. The coefficient of determination R^2 of fitted load/unload in the first cycle was [0.9996, 0.9999]. Meanwhile, R^2 of fitted displacement in the first cycle was [0.9999, 0.9998]. These results show good agreement of the fitted curve with experimental data.

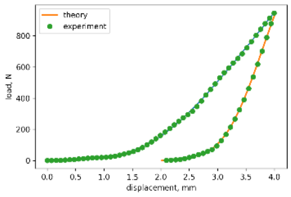

Figure 2: Load displacement relations.

Discussion

Collected experimental data of vertebra load and unload are approximated by using the expressions below:

$$L_k(t) = \sum_{i=0}^{6} a_{ik} t^i \qquad (1)$$

$$d_k(t) = d_{0k} + d_{1k} t \qquad (2)$$

where L_k is external load, d_k is displacement, t is the independent parameter (time), and a_{ik} and d_{ik} are material constants for each load/unload cycle k. The numerical optimization was applied using the *scipy.optimize.curve_fit* function [4].

References

1. C. H. Turner et al., “Experimental Techniques for Bone Mechanics,” in *Bone Mechanics Handbook*, 2nd ed., vol. 7, no. 2, S. C. Cowin, Ed. Boca Raton: CRC Press, 2001.
2. J. B. Volpon et al., “Methods in Bone Biology in Animals: Biomechanics,” in *Osteoporosis Research: Animal Models*, G. Duque and K. Watanabe, Eds. London: Springer Verlag, 2011, ch. 29, pp. 34-35.
3. R. Izzo et al., “Biomechanics of the Spine. Part I: Spinal Stability,” *European Journal of Radiology*, vol. 82 no. 1, pp. 118-126, 2012.
4. P. Virtanen et al., “SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python,” *Nature Methods*, vol. 17 no. 3, pp. 261-272, 2020.

Acknowledgements

We thank veterinarians Dr. J. Šengaut and Dr. L. Labanauskaite for their help in the experiment.