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Short Communication

Finite element method in equine orthopedics

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The finite element method (FEM) is an engineering resource used to predict the stresses in structures that have complex geometries, specific material properties and are subject to complex loading patterns, being widely used in medical and biological research. It has the advantage of being a noninvasive and accurate method, which provides quantitative and detailed data about the physiological reactions that can occur in the tissues [1-5].

In equine medicine, FEM has been used to study the biomechanical behavior and stress distribution in different clinical problems. Hinterhofer, et al. [6], analyzed the stress distribution (von Mises) and the displacement of the hoof capsule with four types of horseshoes. McClinchey, et al. [7] investigated how different shapes of the hoof (angle and length of the toe) affect the stress distribution of tension and displacements in the horn tissue). O'Hare, et al. [5] evaluated the stress distribution in the first phalanx to identify critical points that lead to the occurrence of sagittal fractures in this bone. Likewise, other studies have used a FEM to understand the mechanical characteristics that may predispose to injuries to the bones of the fetlock joint and cannon bone [8-10]. In a recent study, the impact of subchondral femoral cysts on the street distribution at the distal end of the equine femur was investigated [11]. All of these studies that present such important information for understanding of the biological compartment and the cause of many problems in equine orthopedics are possible only using the FEM.

To obtain a finite element model, information about the material's geometry and properties (Young's modulus and Poisson's coefficient) is necessary. There are a large number of publications that have dedicated themselves to determining these properties in the most diverse types of biological tissues. Currently available imaging methods, such as computed tomography or magnetic resonance imaging, provide an assessment of bone architecture, which allows precise reconstruction of its geometries [12,13]. These imaging methods provide not only the external contours, but also the internal geometry of the anatomical structures. In specific software, a segmentation process is applied, based on the differences in the gray level values of the image pixels, which depends on the radiopacity of the tissue [14-17].

From the DICOM files (Digital Imaging and Communications in Medicine) generated by the imaging methods of the region of interest, we can apply software to convert them into a three-dimensional file. The following steps for constructing the finite element can be summarized in: segmentation and discretization, which is the attribution of each pixel/voxel of the images to a specific material (cortical or spongy bone, cartilage ...); three-dimensional reconstruction of the geometry of the various components of the model, followed by the application of enhancement filters (surface smoothing); the creation of the computational mesh (geometry is subdivided into a large finite number of geometrically simple domains (elements) connected at its vertices (nodes)); and the attribution of material properties to the various parts of the model (Young's modulus and Poisson's coefficient) [12,16,18].

After completing these steps, the finite element model is ready to be used to simulate loading conditions, through the application of desired load conditions and limits. The result is graphical representations of the stress distributions over the region of interest, which provides researchers with a deeper view of the biomechanical behavior of materials (bones, tissues, implants), which allows better projection of strategies for the prevention and treatment of orthopedic injuries [13].

More Information

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Several softwares are available to perform the different steps in the elaboration of FEM. The most frequently used are: Amira (Visage Imaging, Berlin, Germany), Simulia/Abaqus (Dassault Systèmes, RI, USA), Ansys (Ansys Inc., PA, USA), Mimics (Materialise, Leuven, Belgium), Solidworks (Dassault Systèmes, RI, USA), MSC Mentat (Marc Schwendler Corp., CA, USA).

It is worth mentioning that the correct construction of the finite element and interpretation of the results is based on a broad knowledge of physical, mathematical, and engineering concepts, in addition to functional anatomy and biology of the tissues, so the formation of a multidisciplinary team is strongly recommended to conduct these studies.

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