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Short Communication

Finite element method in equine orthopedics

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More Information

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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].

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.

References

1. Gilbertson LG, Goel VK, Kong WZ, Clausen JD. Finite element methods in spine biomechanics research. Crit Rev Biomed Eng. 1996; 23: 411–473.
   PubMed: https://pubmed.ncbi.nlm.nih.gov/9017345/
2. Lisiak-Myszke M, Marciniak D, Bieliński M, Sobczak H, Garbacewicz Ł, et al. Application of finite element analysis in oral and maxillofacial surgery: A literature review. Materials. 2020; 13: 3063.
   PubMed: https://pubmed.ncbi.nlm.nih.gov/32659947/
3. Mehta F, Joshi H. Finite element method: An overview. J Dent Med Sci. 2016; 15: 38–41.
4. Necas L, Hrubina M, Cibula Z, Behounek J, Krivanek S, et al. Fatigue failure of the sliding hip screw–clinical and biomechanical analysis. Comput Methods Biomech Biomed Engin. 2017; 20: 1364–1372.
   PubMed: https://pubmed.ncbi.nlm.nih.gov/28793805/
5. O'Hare LMS, Cox PG, Jeffery N, Singer ER. Finite element analysis of stress in the equine proximal phalanx. Equine Vet J. 2013; 45: 273–277.
   PubMed: https://pubmed.ncbi.nlm.nih.gov/22943561/
6. Hinterhofer C, Stanek C, Haider H. Finite element analysis (FEA) as a model to predict effects of farriery on the equine hoof. Equine Vet J. 2001; 33: 58–62.
   PubMed: https://pubmed.ncbi.nlm.nih.gov/11721570/
7. McClinchey H, Thomason J, Jofriet J. Isolating the effects of equine hoof shape measurements on capsule strain with finite element analysis. Vet Comp Orthop Traumatol. 2003; 16: 67-75.
8. Harrison SM, Whitton RC, Kawcak CE, Stover SM, Pandy MG. Evaluation of a subject-specific finite-element model of the equine metacarpophalangeal joint under physiological load. J Biomech. 2014; 47: 65–73.
   PubMed: https://pubmed.ncbi.nlm.nih.gov/24210848/
9. Les CM, Keyak JH, Stover SM, Taylor KT. Development and validation of a series of three-dimensional finite element models of the equine metacarpus. J Biomech. 1997; 30: 737–742.
   PubMed: https://pubmed.ncbi.nlm.nih.gov/9239555/
10. McCarty CA, Thomason JJ, Gordon KD, Burkhart TA, Milner JS, et al. Finite-Element Analysis of Bone Stresses on Primary Impact in a Large-Animal Model: The Distal End of the Equine Third Metacarpal. Plos One. 2016; 11: e0159541.
    PubMed: https://pubmed.ncbi.nlm.nih.gov/27459189/
11. Frazer LL, Santschi EM, Fischer KJ. Impact of a void in the equine medial femoral condyle on bone stresses and peak contact pressures in a finite element model. Vet Surg. 2019; 48: 237–246.
    PubMed: https://pubmed.ncbi.nlm.nih.gov/30556152/
12. Galbusera F, Cina A, Panico M, Albano D, Messina C. Image-based biomechanical models of the musculoskeletal system. Eur Radiol Exp. 2020; 4: 49.
    PubMed: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7423821/
13. Gföhler M, Peham C. What can finite element analysis tell us? Equine Vet J. 2013; 45: 265–266.
14. Carvalho LE, Sobieranski AC, von Wangenheim A. 3D Segmentation Algorithms for Computerized Tomographic Imaging: a Systematic Literature Review. J Digit Imaging. 2018; 31: 799-850.
    PubMed: https://pubmed.ncbi.nlm.nih.gov/29915942/
15. Imai K. Computed tomography-based finite element analysis to assess fracture risk and osteoporosis treatment. World J Exp Med. 2015; 5: 182-187.
    PubMed: https://pubmed.ncbi.nlm.nih.gov/26309819/
16. Rahmat MF. Thuku IT. Review of tomographic imaging using finite element method. Sensors and Transducers. 2011.
17. Tawhai MH, Hunter P, Tschirren J, Reinhardt J, Mclennan G, et al. CT-based geometry analysis and finite element models of the human and ovine bronchial tree. J Appl Physiol (1985). 2004; 97: 2310–2321.
    PubMed: https://pubmed.ncbi.nlm.nih.gov/15322064/
18. Meira JBC, Jikihara AN, Capetillo P, Roscoe MG, Cattaneo PM, et al. Finite element analysis in dentistry. In E Sacher & R. França (Eds.), Dental Biomaterials. 2018; 67–89.