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Three-dimensional Finite Element Method Analysis of Biomechanical Characteristics of Lumbar Vertebra Manipulation

Zhang Lei[1,a], Yuan Haiguang[2,b,*], Gu Xinxin[1,c]

[1]*Shaanxi University of Chinese Medicine, Xianyang, Shaanxi, 712046, China*
[2]*Affiliated Hospital of Shaanxi University of Chinese Medicine, Xianyang, Shaanxi, 712000, China*
[a]*1076925258@qq.com,* [b]*407089398@qq.com,* [c]*2934307331@qq.com*
[*]*Corresponding author*

Abstract: *In order to explore and summarize the biomechanical characteristics of manipulation techniques using three-dimensional finite element analysis, reveal the mechanism of action of the techniques, and provide objective basis for the safety and optimization of the techniques. We searched for articles related to the biomechanical characteristics of lumbar manipulation techniques analyzed using three-dimensional finite element method in PubMed, Web of Science, CNKI database, Wanfang database, and VIPP database since the establishment of the database. The search term is "finite element analysis, biomechanics, lumbar spine, thoracolumbar spine, spine, manipulation, and massage". A total of 1238 articles were retrieved, and 41 articles that met the literature criteria were ultimately included. Resultly, the research on the biomechanical characteristics of lumbar spine manipulation techniques using three-dimensional finite element analysis mainly focuses on lumbar spine rotation techniques, oblique pull techniques, and extension and compression techniques. The research can objectively and accurately reflect the stress and displacement changes of various vertebral tissues during the manipulation process, providing standardized and standardized data support for guiding clinical practice, and improving clinical efficacy through manipulation optimization.*

Keywords: *Finite element analysis; Biomechanics; Spine; Lumbar spine; manipulation*

1. Introduction

Manipulation methods are one of the non -surgical therapies for the treatment of lumbar disc herniation and other waist and leg diseases. The curative effect is clear, the cost is low, and the clinical application is extensive. However, due to the weak basic research, the mechanism of action has not been fully clarified, and the lack of objective norms and standardization of method treatment, the international recognition of manipulation methods is not high [1]. Many scholars analyze the biolio mechanisms of lumbar spine manipulation through animal models, human body specimens, and finite element analysis methods. However, due to the limitations of trials, difficulty in taking materials, and insufficient biological changes, most of the data obtained cannot be directly used to clinical [2]. In recent years, the research of finite element computer technology in spinal biomechanics has developed rapidly. The three -dimensional finite element model of the spine has begun to be established and continuously improved. Such technologies are based on image CT scanning, three -dimensional reconstruction, threshold division, and material assignment. The system performs computer simulation, which can be intuitive, dynamic, and effective simulation of the stress, strain and displacement changes of the spine structure under the condition of the required conditions [3,4]. It has the advantages of economics, quantitativeness, accuracy and repetitiveness. Biomedicine problems in spine mass is ideal.

2. Overview of lumbar spine mass biomechanics finite element

Since Brekelmas [5] and Ryblcki [6] introduced finite element technology into the biomechanical research of spine orthopedics in 1972, in the past 30 years, domestic and foreign scholars have used this technology to analyze the characteristics of human spine mechanics, from the two -dimensional finite element model to the three -dimensional limited finite, from the spine structure to the soft tissue, the research of finite element technology in the spine field is gradually deepened. In 2002, Bi Sheng et

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al. [7] analyzed the biomechanical characteristics of the lumbar vertebral traction process. After the new century, spinal mass finite element research objects also entered the level of fluid mechanics and streaming coupling in a single spine and soft tissue. The finite element method gradually became an important tool for studying the spinal mechanics structure. In recent years, domestic and foreign scholars have used the limited element technology to analyze lumbar spine rotation methods, lumbar vertebral oblique wresting methods, lumbar vertebral extension methods, and changes in the internal and external stress of the lumbar spine in the lumbar spine. The purpose of these studies is to explore the mechanism of spinal diseases in the treatment of spinal diseases, and provide theoretical and data support to optimize existing spine massage methods and ensure the safety and effectiveness of techniques. The article reviews the biomechanical characteristics of the three -dimensional finite element method.

3. Data and methods

3.1. Information and source

We searched for the first authors for this study as of July 2023. The deadline for disorderly documents was from library construction to July 2023. The Chinese databases that we searched included CNKI, Vipp, and Wanfang databases, and the English databases included Pubmed and Web of Science databases. The keywords we searched for included "finite element analysis, biomechanics, spine, lumbar spine, manipulation". The type of literature was review article including related parties, real reports and case reports. In the end, we retrieved a total of 1238 literature, including 152 English literature and 1086 Chinese literature. The literature search process is shown in Figure 1.

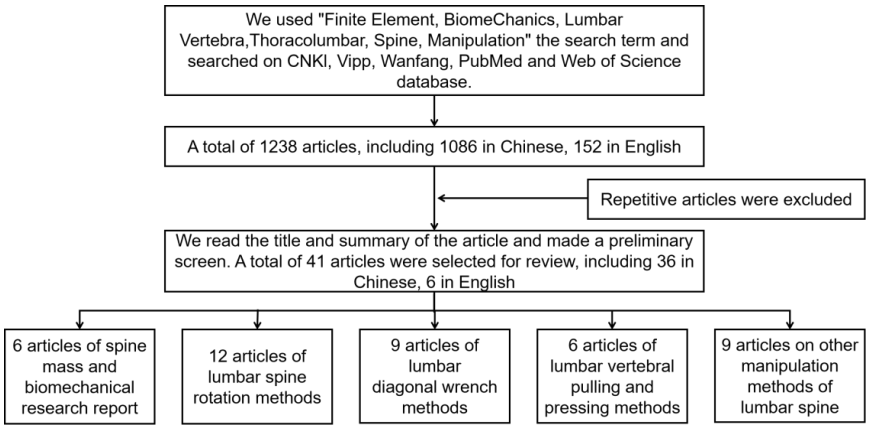

Figure 1: Literature search process

3.2. Entry Group Standard

3.2.1. Incident in the standard

(1) The content described in the article must be related to the application of the three -dimensional finite element method in the application of biomedicism in lumbar spine. (2) The point of view is clear and the analysis of comprehensive articles; (3) Select recent articles published in authoritative journals in the same field。

3.2.2. Repeatability of standards

During the research process, we ensured repeatability of quality standards.

3.2.3. Literature quality assessment and data extraction

There were 42 literature that met the standards. Among them, documents [1-6] were reports on spinal manipulation techniques and spinal biomechanics. Documents [8-16] were reports from the three-dimensional finite element method in the research of lumbar diagonal wresting method. Documents [17-22] were reports on the application of three-dimensional finite element method in biomechanical research. Documents [23-30] were reports from the three-dimensional finite element method in other manipulation methods.

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4. Results

4.1. The lumbar spine rotation method

Represented by the sitting point rotation method of the lumbar spine is the improvement of Professor Feng Tianyou through the traditional manipulation method. It is an important part of the method of lumbar spine. This massage manipulation mainly acts on the nuclear, cartilage endboard, vertebral bow root, vertebral arch, and joints, etc. [4], and widely used in clinical application and accurate efficacy. Through the three -dimensional finite element analysis, research and evaluation of the mechanism, security, and optimization of the method can be studied and evaluated. Wu Shan et al. [31-35] loaded the lumbar vertebral point rotation method of lumbar vertebrae on the L4-5 three-dimensional finite element model. It was found that the stress and displacement of this technique were mainly concentrated on the lateral annulus fibrosus, while the stress of the intervertebral disc was much smaller than the maximum stress of the posterior structure of the vertebral body. In order to expand the indications of this method, there are research to rotate the degenerate lumbar spine slip model, and find that the stress and displacement of this method were mainly concentrated on the lateral annulus fibrosus, while the stress of the intervertebral disc was much smaller than the maximum stress of the posterior structure of the vertebral body [36]. Some scholars build mild and moderate degeneration lumbar spine three -dimensional finite element models for research. It is found that normal models, mild degeneration models, and moderate degenerative model displacement are reduced by 36% and 59%, and the stress is reduced by 22.3%and 45.2%. And moderate degeneration of the intervertebral disc, the pressure in the disconneys is higher than the mild degeneration. The above studies show that as the degree of degeneration of the lumbar spine increases, the efficacy of the massage manipulation has deteriorated [8]. Wang Fei et al. [36] found that with the rotation of the lumbar vertebrae, the stress of the intervertebral disc is gradually increased to the maximum. When the lumbar vertebrae recovered the middle vertical position, the sepanic stress gradually decreased. This conclusion is similar to the research conclusion of Wu Shan et al: The intervertebral disc stress gradually increased and transmitted to the outside during the rotation method without being similar to the center of the intervertebral disc. Most scholars [3,32,37] about the mechanism of technical action tended to improve the mechanical balance of the corresponding lumbar spine. During the operation process, the back of the lumbar spine tissue is pulled. The volume of the space is increased, the nerve root canal is passively expanded, the roots have a relative displacement, the local adhesion is loosened, and the pressure and stimulation of the nerve root are reduced. For research on the safety of techniques, Xu Haitao et al. [33,38] found that the maximum twisting distance that normal intervertebral discs could withstand was 45. 1Nm, the maximum stress value was 1.887 × 107Pa, and the maximum stress value of the small joint was 8.767 × 105Pa, and the small joint, and the small joints were 8.767 × 105Pa, and while, and the small joint, During the operation process, whether it is stress or torque is far less than the normal stress and torque force of the intervertebral disc and joints, but in the process of operation, the angle of the side bending and bending cannot be increased at will. The hip joints will also have obvious displacement and stress concentration [39]. Therefore, Yu Jinjue et al. [40] recommended that clinical method operation is 40 ° or 60 °, and patients with gorge cracks should not be used [7]. Tian Qiang [41] compared the biomechanical properties of seated fixed-point rotation and straight waist rotation, and found that seated fixed-point rotation is safer.

4.2. Lumbar vertebral oblique wresting method

Lumbar vertebral oblique wresting method is one of the common techniques in lumbar spine manipulation, but the subjectivity of the technique operation is too strong, lack of quantitative and standardized indicators [8], which limits the promotion and development of the method. Therefore, it is becoming increasingly. The more scholars study the mechanism and safety of this method, and the optimization method is optimized in order to improve the clinical efficacy. Tian Cong et al. [10,11] constructed the L4-5 finite element model with normal functions. When loading through the method, the stress concentration of the small and medium joint contact surface was mainly located on the opposite side of the oblique wresting method. During the vertebral body, the joints of the joints of the joints and the root of the vertebral arch are the stress concentration side. Tang Shujie [12] compared the lumbar spine rotation method with the oblique wresting method. The change is mainly concentrated in the vertebral structure of the rotating side when loading the method, but the stress of the oblique wresting method is higher than the straight waist rotation method. Shu Xinnong [13] found that the oblique wresting method should be 1.79 times and 3.03 times of the sitting straight waist rotation method respectively, by loading the axial compression load and rotating torque load through

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comparative techniques. The biomechanical effect is better than the rotation method [14], but the research of Chen Jinfeng et al. [38] pointed out that the sloping method is more safe. Therefore, this method was more suitable for conservative treatment of lumbar spondylonia. For more research on the safety of techniques, Xu Haitao [33] observed that when the oblique pulling technique was used for loading, the intervertebral disc stress would protrude backwards. For lumbar spinal canal with a small buffer room at this time, if patients need to be stensed, this method may not be applicable. Tian Cong [11] constructed the joints of the joints and the destruction model to load it. It was found that when the failure side of the joint was the stress concentration side, the stress was very close to the safety limit. But when the method of stress was concentrated on the root of the vertebral bow and the vertebral body at the time of the spiny ejaculation, the maximum stress value was far less than the safety limit set by the research institute, so the part was basically not affected by the safety of the method. Lu Yu [9] simulated the front flexion 30 °, the horizontal level is 0 °, and the lower discoloration of the seductive disk and the transition between the intervertebral disc and the nerve root of the intervertebral disc. The decrease in the decrease between the nerve roots may not be conducive to alleviating the symptoms of nerve root compression. In order to improve the safety and efficacy of traditional oblique wresting methods, and optimize the operation process, some scholars adjusted the instantaneous increase of the traditional oblique wresting method to the oscillation of the back and forth and the difference between the force and displacement during the operation process of the operation. After analysis, the conclusion showed that the average displacement and stress of the improvement of the improvement oblique wrenched in the intervertebral disk and the joints of the joints were higher than that of the traditional oblique wrench. The change of the average stress and the displacement value was significantly reduced with the degree of degeneration of the lumbar disc [13]. The improvement method can more adjust the space position of the segment of the disappear or degenerate segment, so that the lumbar vertebral body generates horizontal and rotation and displacement instead of the upper and lower positions [10]. However, some researchers had pointed out that with the degeneration of the lumbar spine, the relative displacement and maximum acceleration of the two techniques were attenuated, and the attenuation rate of the oblique wresting method was improved. At the same time, as the force increases, the difficulty of improving the operation of the oblique wrests can also increase. Therefore, considering multiple factors such as comprehensive clinical efficacy and safety, the choice of techniques and force during the operation and the size of the force must be selected after clinicians judge the specific situation of the patient.

4.3. Lumbar vertebral pull -off and pressing method

The method of pulling stretching is one of the "three steps and three methods" created by Professor Song Guijie. It is often used in the treatment of lumbar disc herniation, the simplicity of lumbar spine compression fractures, and lumbar spine joint disorders. Compared with the oblique wrenching method and rotation method of the lumbar spine, the research mechanism of the related biomechanical action mechanism of lumbar spine plug -in and extension is more mature. The changes, the scope and action mechanism [18] has been applied to the treatment of a single -stage thoracic lumbar spine compression fracture, and it has been proven that the effect of the method generated is close to the model effect, with a clinical effective rate of 93.00%. With the maturity of the mechanism of biomechanics of techniques, the research direction of the pull -out and extension method gradually improved the clinical efficacy and excessive safety of the clinical efficacy. Li Jubao [18] found that when the lumbar spine was 30 °, the spine sudden displacement was large. When the back extension is 10 °, the transition of the small joints of the vertebral body is large. The extension of the back edge of the body was the most obvious. The inner layer of the pulmuclear edge was larger than the outer displacement. The inner layer of the fiber ring was larger than the outer displacement. By studying the model deformation damage, Yang Xuefeng [19] concluded that the clinical treatment effect was the best when extending the suture after comprehensive analysis. When the forward flexion was 30 °, the effect was the worst. Zhang Xiaogang [17,20] observed the above three positions and retreated to the simulated cloud map of the lumbar spine segment. It was found that this technical operation may change the relative displacement between the intervertebral disc and the nerve root, promoting the relative displacement or looseness between the nucleus pulposus and the nerve root. The effect of decompction and sticking and extension and pressing the method of pressing on the human lumbar spine was a safe operation therapy. Shang Yong [21] constructed the L3-4 motion segment to mild degeneration and moderate degeneration model to load the work conditions of the multi-extension method.

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4.4. Other lumbar massage manipulation

Traditional massage methods are one of the means of conservative treatment of lumbar spine diseases. The method is not limited to the lumbar spine rotation, oblique pulp, and extension of the lumbar spine rotation. The elbow method, the stitching method, the inverted gold quilt method, the stand -up method of bending down, and the leveraged positioning method have been confirmed that the efficacy of the clinical practice is precise. Chen Xinyi et al. [22,23] constructed the lumbar disc herniation three-dimensional finite element model to load the elbow in the elbow and found that when the press angle is 15-45 °, the method of the lumbar spine of the affected side was the minimum. The efficacy and safety considerations of the combination of methods were the best effect when pressing the angle of 45 °, and it was pointed out that the efficacy mechanism of the elbow method may be prioritized with the relative displacement of the intervertebral disc and the small joint. Li Qingbing [24] found that the operation of different cycles and durations can increase the degree of lumbar vertebrae. Among them, the cycle was 1.25s, and the operation was safer under 20S operating conditions, the efficacy of which was more stable. Zhou Ling [25] simulated the golden surgery on the spine bed, it was found that the maximum stress value was mainly concentrated on the back structure of the lumbar spine at the root of the bather, the vertebral section and the intervertebral joints. The stress showed a trend of linear growth [27], and for mild and moderate degenerative changes, the best top push height was 8cm [28]. And the height and area of the intervertebral pores gradually stabilized. The height and area of the intervertebral hole in the lumbar spine increased slightly, and the changes were not obvious [29,30]. Wang Lin analyzed the finite element analysis of lumbosacral joint disorders to bending down. The joints were shifted forward and down, and the joints of the joints were increasing. This clarified the mechanism of bending down and stands up, and proved that the flexion method was effective, safe and reliable in treating lumbosacral joint diseases. Lv Lijiang [30] analyzed the effects of leveraging positioning methods on lumbar discalization biomechanics, and found that the leverage positioning method can make the fiber ring have a significant recovery effect. So when the spinal cord nucleus approached the front and middle, the pressure on the front and middle can increase.

5. Discussion

In recent years, with the development of computer finite element technology, the standardization and quantitative research of traditional massage techniques have made great progress, but there are still insufficient: (1) Although different materials have been used instead of different human tissues to build spine models, model construction has a single source, lack of representativeness, and most of the model building is in staggering, and the lack of overall biomarry of the spine is considered. (2) At present, most research on the mechanism of method action mechanisms, most of the research results tend to promote the spine exogenous stabilization system during the process of the joint process, the displacement of the fiber ring, and the stress change of the fiber ring. The position changes, alleviating the pressure of the nerve root, thereby achieving the purpose of the treatment, and the intraurate internal pressure of the nucleus will not increase or decrease. Only when there is a longitudinal stretch of the method, the intraurate pressure in the nucleus may be reduced [30]. Therefore, when the clinical operation is aimed at patients with spinal stenosis or lumbar disc herniation. Increase the security of the operation. (3) The research results and clinical practice lack a unity. Most scholars obtain the safety operating effects and angles of the safety operations through the three -dimensional finite element method, and optimize the methods. And there are few clinical applications of research results. At present, only the method of pulling and pressing and pressing has been applied to the clinical clinical [17] and the clinical effect is excellent. (4) Although the mechanism of biomechanical effects of lumbar spine techniques has been used to analyze the lumbar spine techniques, the research on biomechanical research combined with the combination of the three -dimensional finite element method and spine techniques is relatively late, so the research on techniques is generally limited to oblique tip and rotation. Laws, plugging and pressing methods, etc., the traditional Chinese medicine traditional methods are charged, and whether there are differences between other techniques and the above methods of the above -mentioned methods still need to be expanded to fill the research gap in this field. In short, with the continuous progress of finite element technology, it is expected to continue to be standardized, objective, and applied in future research. Patients formulate individualized treatment plans in order to improve clinical efficacy and better serve patients.

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