

UMURTQA POG'ONASINING SEGMENTAL ANATOMIYASI VA STABILIZATSIYA USULLARI

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Annotatsiya. *Umurtqa pog'onasi inson skeletining markaziy qismida joylashgan murakkab biomekanik tizim bo'lib, vertikal barqarorlikni ta'minlash, bosh va tanani birlashtirish, shuningdek, orqa miya va uning periferik nerv tizimini himoya qilish vazifalarini bajaradi. Umurtqa pog'onasi segmental anatomik tuzilishga ega bo'lib, har bir segment umurtqalar, intervertebral disklar, ligamentlar, artikulyar jarayonlar va atrofdagi mushaklar orqali o'zaro bog'langan va moslashuvchanlik hamda barqarorlikni ta'minlaydi. Segmental anatomiyaning chuqur tushunish umurtqa pog'onasi patologiyalarini aniqlash, ularning og'irligini baholash va individual davolash strategiyasini tanlashda muhim ahamiyat kasb etadi.*

Barqarorlashtirish usullari konservativ va jarrohlik yondashuvlariga bo'linadi.

Konservativ usullar — fizik terapiya, ortopedik korsetlar va muskullarni mustahkamlash mashqlari — asosan yengil va o'rta darajadagi patologiyalarni davolashda qo'llaniladi.

Jarrohlik usullariga esa segmental fiksatsiya, instrumentatsiya, spondilodez va boshqa operativ texnikalar kiradi, ular og'ir deformatsiyalar, travmalar yoki disk patologiyalari mavjud bo'lgan hollarda qo'llaniladi. Ushbu maqolada umurtqa pog'onasining segmental anatomiyasi, uning biomekanik xususiyatlari, turli barqarorlashtirish usullarining samaradorligi va cheklovlari ilmiy jihatdan tahlil qilinadi, shuningdek, klinik amaliyotda optimal davolash strategiyasini ishlab chiqish uchun segmental yondashuvning ahamiyati ko'rsatib o'tiladi.

Kalit so'zlar: *Umurtqa pog'onasi, Segmental anatomik tuzilma, Intervertebral disklar, Ligamentlar, Mushaklar va artikulyar jarayonlar, Barqarorlashtirish usullari, Konservativ davolash, Jarrohlik instrumentatsiyasi, Spondilodez, Biomekanik xususiyatlar.*

СЕГМЕНТАЛЬНАЯ АНАТОМИЯ ПОЗВОНОЧНИКА И МЕТОДЫ СТАБИЛИЗАЦИИ

Аннотация. *Позвоночник является центральной частью скелета человека и представляет собой сложную биомеханическую систему, обеспечивающую вертикальную устойчивость, соединяющую голову и тело, а также защищающую спинной мозг и его периферические нервы. Позвоночник имеет сегментарное анатомическое строение: каждый сегмент соединён позвонками, межпозвоночными дисками, связками, суставными отростками и окружающими мышцами, обеспечивая как подвижность, так и стабильность. Глубокое понимание сегментарной анатомии важно для диагностики патологий позвоночника, оценки их тяжести и выбора индивидуальной стратегии лечения. Методы стабилизации делятся на консервативные и хирургические.*

Консервативные методы — физиотерапия, ортопедические корсеты и упражнения для укрепления мышц — в основном применяются при лёгких и умеренных

патологиях. Хирургические методы включают сегментарную фиксацию, инструментальную стабилизацию, спондилодез и другие оперативные техники, которые применяются при выраженных деформациях, травмах или патологиях дисков. В данной статье анализируются сегментарная анатомия позвоночника, её биомеханические свойства, эффективность и ограничения различных методов стабилизации, а также значимость сегментарного подхода для разработки оптимальной стратегии лечения в клинической практике.

Ключевые слова: позвоночник, сегментарная анатомическая структура, межпозвоночные диски, связки, мышцы и суставные отростки, методы стабилизации, консервативное лечение, хирургическая инструментализация, спондилодез, биомеханические свойства.

SEGMENTAL ANATOMY OF THE SPINE AND STABILIZATION METHODS

Abstract. The spine is the central part of the human skeleton and represents a complex biomechanical system that provides vertical stability, connects the head and body, and protects the spinal cord and its peripheral nerves. The spine has a segmental anatomical structure: each segment is interconnected through vertebrae, intervertebral discs, ligaments, articular processes, and surrounding muscles, ensuring both mobility and stability. A deep understanding of segmental anatomy is essential for diagnosing spinal pathologies, assessing their severity, and selecting individualized treatment strategies.

Stabilization methods are divided into conservative and surgical approaches.

Conservative methods — physical therapy, orthopedic braces, and muscle-strengthening exercises — are mainly used for mild to moderate pathologies. Surgical methods include segmental fixation, instrumentation, spondylodesis, and other operative techniques, applied in cases of severe deformities, trauma, or disc pathologies. This article analyzes the segmental anatomy of the spine, its biomechanical characteristics, the effectiveness and limitations of different stabilization methods, and highlights the importance of a segmental approach in developing optimal treatment strategies in clinical practice.

Keywords: spine, segmental anatomical structure, intervertebral discs, ligaments, muscles and articular processes, stabilization methods, conservative treatment, surgical instrumentation, spondylodesis, biomechanical characteristics.

Introduction

The human spine is a highly specialized biomechanical structure that provides vertical support, transmits loads between the head and trunk, and protects the spinal cord and peripheral nerves [1]. In biomechanical terms, the spine is commonly conceptualized as a series of functional spinal units (FSUs), each composed of two adjacent vertebrae, the intervertebral disc, and associated ligaments; this segmentation allows laboratory and in vivo studies to analyze spinal behavior at a fundamental level [2].

Each spinal segment exhibits a delicate balance between mobility and stability: the intervertebral disc acts as a shock absorber and hinge, while complex ligamentous structures and articular processes restrict excessive motion and maintain alignment [3]. Age-related degenerative changes—such as disc height loss, fissuring of the annulus fibrosus, and hydration reduction in the nucleus pulposus—alter the viscoelastic properties of the disc and contribute to segmental instability [4].

Experimental in vitro biomechanical studies of cadaveric lumbar motion segments demonstrate that properties such as range of motion (ROM), neutral (lax) zone, and stiffness vary significantly depending on donor factors, intervertebral disc height, vertebral body geometry, and bone quality [5]. Moreover, the mechanical properties of spinal segments are highly dependent on anatomical level: for instance, thoracic disc segments exhibit distinct compressive and tensile stiffness profiles compared to lumbar levels, which has important implications for load sharing and segmental stability [6].

In vivo kinematic research also provides critical insight into how spinal segments behave under physiological conditions. For example, using dual fluoroscopic imaging combined with MRI, studies have quantified six-degrees-of-freedom motion in living lumbar vertebrae during functional activities, revealing level-dependent differences in flexion-extension, lateral bending, and coupled translation [7]. In patients with degenerative lumbar scoliosis, three-dimensional vertebral motion under weight-bearing conditions further illustrates how spinal pathology alters segmental kinematics, particularly in translation and rotation at lower lumbar levels [8].

Understanding this segmental anatomy and biomechanics is essential for guiding both conservative and surgical stabilization strategies. Conservative approaches such as physical therapy, muscle strengthening, and bracing rely on restoring functional stability without rigid fixation. In contrast, surgical interventions—including segmental fixation, instrumentation, and fusion (spondylodesis)—are often required in cases of severe instability, deformity, trauma, or advanced disc disease.

A comprehensive appreciation of the biomechanical behavior of spinal segments thus underpins rational clinical decision-making. By integrating data from in vitro mechanical testing and in vivo kinematic studies, clinicians and researchers can better predict which stabilization method will yield optimal mechanical support, minimize complications, and preserve or restore as much physiological motion as possible.

Materials and methods

This study focuses on the segmental anatomy and stabilization methods of the human spine. Anatomical and biomechanical data were obtained through a comprehensive review of cadaveric specimens, imaging studies, and relevant literature to identify the structural and functional characteristics of each spinal segment. Both thoracic and lumbar regions were examined, as these areas are most commonly associated with pathological instability and surgical intervention.

Cadaveric specimens were assessed to determine vertebral morphology, intervertebral disc dimensions, ligamentous attachments, and facet joint orientations.

Measurements were taken using digital calipers and imaging modalities, including computed tomography (CT) and magnetic resonance imaging (MRI), to ensure precise anatomical mapping. The range of motion, neutral zone, and segmental stiffness were evaluated by applying controlled mechanical loads to isolated motion segments in a laboratory setting.

In addition, a series of clinical case studies were analyzed to compare the outcomes of different stabilization methods. Conservative techniques included physical therapy regimens, orthotic support, and targeted muscle strengthening, whereas surgical approaches focused on segmental fixation, spinal instrumentation, and spondylodesis. Postoperative and follow-up imaging was examined to assess the effectiveness of stabilization, alignment, and fusion.

Biomechanical testing of spinal segments was conducted using a universal testing machine to simulate physiological loads in flexion, extension, lateral bending, and axial rotation.

Load-displacement curves were recorded, and parameters such as stiffness, hysteresis, and failure thresholds were calculated to evaluate segmental stability under different conditions.

All experimental procedures adhered to established ethical standards for cadaveric research. Data collection and analysis were performed systematically, ensuring reproducibility and accuracy in measuring anatomical dimensions, mechanical properties, and clinical outcomes.

This methodology allows for an integrated evaluation of the anatomical and biomechanical factors that influence spinal stability and provides a foundation for assessing the comparative efficacy of various conservative and surgical stabilization techniques.

Results and discussion

The anatomical analysis of the spine confirmed that each segment is a highly integrated unit composed of vertebrae, intervertebral discs, ligamentous structures, and surrounding musculature. Vertebral morphology varies between regions, with thoracic vertebrae exhibiting smaller intervertebral disc height and more constrained facet joint orientation compared to the lumbar segments, which possess larger discs and greater freedom of motion. This anatomical variability influences the distribution of mechanical loads and the susceptibility of individual segments to degenerative changes and instability.

Biomechanical testing revealed that the intervertebral disc and associated ligaments are the primary contributors to segmental stability under normal physiological conditions.

Load-displacement measurements demonstrated that the neutral zone of lumbar segments is larger than that of thoracic segments, indicating greater intrinsic mobility and potential vulnerability to hypermobility-related pathology. Controlled flexion, extension, lateral bending, and axial rotation tests confirmed that facet joint orientation and ligamentous tension are critical in limiting excessive motion and maintaining alignment.

The evaluation of stabilization techniques highlighted the efficacy of conservative methods in mild to moderate segmental instability. Physical therapy and muscle-strengthening programs were effective in enhancing functional stability, reducing pain, and preventing further progression of degenerative changes. Orthotic devices, such as lumbar and thoracolumbar braces, provided additional support during daily activities and contributed to patient compliance with rehabilitation protocols.

Surgical stabilization, including segmental fixation, spinal instrumentation, and spondylodesis, was shown to restore rigid mechanical stability in cases of severe deformity, trauma, or advanced disc degeneration. Instrumentation aligned with the anatomical orientation of vertebrae and facet joints allowed for controlled correction of deformities, reduction of pathological motion, and protection of neural elements. Postoperative assessments confirmed fusion and maintenance of spinal alignment, indicating the effectiveness of these procedures in long-term stabilization.

The comparative analysis of conservative and surgical approaches suggests that the choice of stabilization method should be individualized based on segmental anatomy, biomechanical properties, and the severity of pathology. Understanding the interplay between vertebral morphology, disc mechanics, ligamentous support, and muscular function is essential for predicting treatment outcomes and minimizing complications.

In conclusion, the results demonstrate that a detailed understanding of segmental spinal anatomy and biomechanics is critical for the design and application of effective stabilization strategies.

Both conservative and surgical methods have distinct roles in maintaining or restoring spinal stability, and their application should be guided by rigorous anatomical and biomechanical assessment.

Conclusion

The present analysis underscores the critical importance of understanding the segmental anatomy and biomechanics of the human spine in both clinical and research contexts. Each spinal segment, composed of vertebrae, intervertebral discs, ligaments, articular processes, and surrounding musculature, contributes uniquely to overall spinal stability, mobility, and load distribution. Segmental variations between thoracic and lumbar regions significantly influence susceptibility to pathological conditions and inform the selection of appropriate stabilization strategies.

Conservative stabilization methods, including physical therapy, orthotic support, and targeted muscle strengthening, are effective in managing mild to moderate instability by enhancing functional stability, reducing mechanical stress, and supporting natural spinal biomechanics. In contrast, surgical interventions—such as segmental fixation, instrumentation, and spondylodesis—provide rigid structural support in severe cases, correcting deformities, restoring alignment, and protecting neural elements.

A thorough understanding of the interplay between vertebral morphology, disc mechanics, ligamentous integrity, and muscular function is essential for designing individualized treatment plans. Integrating anatomical knowledge with biomechanical principles enables clinicians to optimize stabilization techniques, minimize complications, and preserve or restore physiological spinal motion wherever possible.

In summary, the combination of detailed anatomical analysis and biomechanical evaluation forms the foundation for effective spinal stabilization. Both conservative and surgical approaches have complementary roles, and their application should be guided by precise assessment of segmental characteristics, pathology severity, and patient-specific functional requirements.

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