Restorative laminoplasty with H-shaped miniplates fixation in intraspinal surgery: a new technology for the reconstruction of the posterior column complex

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Abstract

Objective: To evaluate the mechanical properties and biomechanical effects of different miniplates on restorative laminoplasty, and to explore the clinical outcome of restorative laminoplasty with H-shaped miniplates fixation system in intraspinal surgery.

Methods: Restorative laminoplasty was performed on 3D printing L4 vertebral model, and they were divided into H-shaped miniplates (HSMs) group, two-hole miniplates (THMs) group, and L-shaped miniplates (LSMs) group by different internal fixations. Static and dynamic compression tests were analyzed to investigate the mechanical properties. The static compression tests adopted the speed control mode, and the dynamic fatigue compression tests adopted the load control mode; The biomechanical effects of different miniplates were carried out on the premise of verifying the validity of established L3-L5 finite element model. The finite element study of restorative laminoplasty were divided into normal assignment (NA) group, laminectomy (LAM) group, HSMs group, THMs group and LSMs group. The range of motion (ROM) of L3-L4 and L4-L5 was evaluated in six directions (flexion, extension, left and right bending, left and right rotation). The clinical research studied the outcome of HSMs on maintaining the integrity of spinal canal and the restoration of spinal stability

Results: The “door close” and the collapse of lamina occurred in THMs group and LSMs group, and plate break occurred in LSMs group. However, the phenomenon

was absent in HSMs group, and only plate crack around a screw and looseness of a screw tail cap were found in HSMs group. The sustainable yield load of HSMs group was greater than that of THMs group and LSMs group ($P < 0.05$). No significant difference in yielding-displacement was found between HSMs group and LSMs group ($P > 0.05$), while both were much less than that of THMs ($P < 0.05$). Moreover, the compressive stiffness and the axial displacement under the same mechanical load were arranged as follows: HSMs group > LSMs group > THMs group ($P < 0.05$). The results of dynamic compression test revealed that the peak load of HSMs group could reached 873 N and was 95% of the average yield load of the static compression, and was better than that in THMs group and LSMs group ($P < 0.05$). Besides, according to the fatigue life-peak load diagram, the ultimate load of HSMs group was more than twice that of THMs group or LSMs group. Compared with the LAM group, the ROM in L3-L4 and L4-L5 segments in NA group, HSMs group, THMs group and LSMs group were significantly reduced under the 6 loading conditions. Compared with the NA group, the HSMs group only showed a significant increase in ROM during extension. In THMs group and LSMs group, the ROM increased significantly in flexion, extension, bending, and rotation. The overall trend of ROM and the maximum ROM in diseased segments was as follows: LAM group > LSMs group ≒ THMs group > HSMs group > NA group. During the follow-up period from 13 to 45 months, the spinous process and laminae complex were firmly fixed without displacement or collapse, and no loosening or fracture was observed in HSMs group, and the osteotomy ends of the laminae were completely fused, and no scar or fibrous tissue was observed in the spinal canal, and no recurrence was observed. The average operation time was (115±33.8) min (range, 50-140 min). The average operation time of LAM of single segment and orthotopic replantation of lamina-spinous process complex was (8.2±1.5) min and (12.8±3.6) min respectively. The mean intraoperative blood loss was (115.8±42.4) mL (range, 50-220 mL), and the time in bed was (7.8±1.3) days (range, 6-10 days), and the hospital stay was (11.5±2.3) days (range, 10-18 days). The VAS and JOA scores of all patients were improved compared with those before surgery ($P<0.05$), and the improved rate of neurological function

improvement was 86.7% at one year after surgery. The sagittal diameter and stenosis rate of the spinal canal in diseased segments were slightly decreased compared with those before operation, and the difference was not statistically significant (P>0.05). However, the structure of the spinal canal remained intact, and no compression of the spinal cord occurred after the operation. No spinal cord injury, spinal instability and spinal deformity were found during the follow-up. At 3 months, 6 months and 1 year follow-up, the bone fusion rates were 46.7 %, 96.7 % and 100.0 %, respectively.

Conclusion: The mechanical strength and biomechanical effects of HSMs was superior to THMs and LSMs in maintaining spinal canal enlargement and spinal stability, and was more excellent in fatigue stability and ultimate load. The technology of restorative laminoplasty with HSMs in intraspinal surgery could not only ensure enough operation space, but also anatomically reconstructed the posterior column structure. The new technology maintained the integrity and stability of the reconstructed spinal canal, and prevented the occurrence of limited spinal movement or degeneration of adjacent vertebral after internal fixation. The HSMs fixation was a safe and effective internal fixation method with relatively satisfactory fixation effect and clinical efficacy and low postoperative complications. Additionally, HSMs fixation provided a reliable instrument and fixation technique for restorative laminoplasty after laminectomy, but its long-term clinical efficacy and prognosis still needs further observed and analyzed.

Key words: Laminectomy; Restorative laminoplasty; Replantation; Intraspinal surgery; Biomechanics; Mechanics; Miniplates.

Biography

Guoyin Liu has completed his Master's degree from Medical School of Nanjing University, and is currently a PhD candidate in Nanjing Medical University. He is the doctor-in-charge and associate professor at the Department of Orthopaedics, Jinling Hospital of Nanjing Medical University. He worked mainly on the role of intracellular and extracellular GRP78/Bip in particles-induced periprosthetic osteolysis and rheumatoid arthritis; the clinical application of extracorporeal shock wave therapy, corticosteroid injection, and needle-knife therapy in the treatment of chronic plantar fasciitis; and the application of lamina osteotomy and replantation with miniplate fixation (restorative laminoplasty) in intraspinal occupying lesions. He had been invited

as a speaker to the “World Congress on Virology & Infectious Diseases” during November 20-22, 2017 in Miami, FL, USA, and as a speaker to the International Conference on Biomarker Research in Clinical Medicine scheduled for February 19-21, 2018 in Paris, France (BRCM 2018). He was a member of the Standing Committee of the China Medicine Education Association (CMEA), and a managing director of National Association of Health Industry and Enterprise Management (NAHIEM). He was an editorial board member for Journal of《Orthopaedic Surgery and Research》, 《Innate Immunity》, 《Frontiers in Bioscience-Landmark》, 《Current Molecular Medicine》and《Current Pharmaceutical Design》. He was also an editorial board member for Tianjin Medical Journal, Chinese General Practice , China Medical Herald，New Medicine, Drugs & Clinic, Chinese Traditional and Herbal Drugs, Anhui Medical and Pharmaceutical Journal, Anhui Medical Journal, Translational Medicine Journal, Journal of Medical Research, Health Medicine Research and Practice, Hebei Medicine, Hainan Medical Journal, Zhejiang Clinical Medical Journal, China Modern Medicine, China Modern Doctor, and Henan Medical Research. He have obtained several project: The National Natural Science Foundation of China (NSFC)(82102547), The Natural Science Foundation of Jiangsu Province (BK20181113), The Science and Technology Foundation of Nanjing City (201803059), Youth Science Foundation Project of Jingdu Hospital (20170302), Technological Innovation Foundation of Nanjing Military Region (15ZD020), The Science and Technology Foundation of Nanjing City (201503007) ,Clinical Scientific Project of Wu Jieping Medical Foundation (320-2745-16-115), Technological Innovation Foundation of Nanjing Military Region (14MS046).

About Research Topic

To understand the full value of miniplates on restorative laminoplasty, we need to examine the miniplates from different perspectives. Therefore, in recent years, our team have carried out a series of researches in view of the biomechanical effects on restorative laminoplasty. Our team discussed this question mainly from the following aspects: First, the static and dynamic compression tests of miniplates on 3D printed lamina was to evaluate the acute segmental fixation effect afforded by different Internal fixation system (two-hole, L-shaped and H-shaped miniplates), and to confirm the safety and stability of H-shaped miniplates. Secondly, the finite element analysis of restorative laminoplasty mainly studied the effect of spinal movement (six conditions including flexion, extension, left and right bending, left and right rotation), and the stress distribution of miniplates and responsible segment. Furthermore, the clinical application of restorative laminoplasty with miniplates in intraspinal occupying lesions mainly studied the problem of clinical efficacy, safety, effectiveness, and prognosis. The clinical research also studied the effect of miniplates on maintaining the integrity of spinal canal and the restoration of spinal stability.

About Institution:

Jinling Hospital of Nanjing Medical University, also named as General Hospital of Eastern Theater Command, located in Nanjing, China, is a tertiary hospital.

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