Development of Lever Positioning Manipulation (LPM) from the Perspective of Information Interaction

Lingfeng ZHU[1], Zhizhen LU[2,3], Jie HAN[4], Jieke YANG[5], Yafeng CHEN[3], Lijiang LU[2,3]*

1. Tuina Department of Zhoushan Traditional Chinese Medicine Hospital, Zhoushan 316000, China; 2. Tuina Department of the Third Affiliated Hospital of Zhejiang University of Traditional Chinese Medicine (Zhongshan Hospital, Zhejiang Province), Hangzhou 310005, China; 3 Third Clinical Medical College of Zhejiang University of Traditional Chinese Medicine, Hangzhou 310053, China; 4. Tuina Department of Hubei Provincial Hospital of Traditional Chinese Medicine, Wuhan 430000, China; 5. Tuina Department of Ningbo Second Hospital, Ningbo 315010, China

Abstract The benefits of Lever Positioning Manipulation (LPM) in the treatment of lumbar disc herniation have been widely recognized. The emergence of virtual reality (VR) technology in the field of medicine and the successful application of augmented reality (AR) technology in the field of surgery have brought new thinking to manipulation researchers on the treatment of lumbar disc herniation (LDH) in the era of artificial intelligence (AI). In this study, the development trend and clinical efficacy of VR technology were discussed from the development process of this technology, and the combination of information interaction technology in the field of chiropractic was found from the existing research approach of lever positioning treatment of LDH, in order to provide a useful reference for researchers.

Key words Lever Positioning Manipulation (LPM), Lumbar disc herniation (LDH), Virtual reality (VR), Augmented reality (AR), Mixed reality (MR), Imaging medicine, Spine, Pelvic sagittal parameters, 3D modeling

1 Introduction

The "lever positioning manipulation" (LPM)[1], which was included in the "14th Five-Year Plan" textbook, was founded by Professor Lu Lijiang, Director of the Tuina Institute, Zhejiang University of Traditional Chinese Medicine. As an appropriate technology promotion project in Zhejiang Province, the clinical efficacy of LPM in the treatment of lumbar disc herniation (LDH) has been verified by multiple centers[2-3]. LPM started from Professor Lu's "five-step manipulation method"[4], which combines his own medical experience of more than 30 years. He believed that 90% of LDH patients can be rehabilitated by manipulative reduction, that is, the so-called reversibility, and the clinical symptoms of LDH are strictly classified according to the severity of imaging data when diagnosing the disease. When operating LPM, it is necessary to find the fulcrum according to the patient's image and clinical signs, and grasp the size and direction of the force. The invention of LPM simplifies the operation steps of traditional bone setting manipulation, so that a complete set of bone setting manipulation can be completed only by finding a simple biological lever[5]. With the development of medical information, the application of virtual reality (VR), augmented reality (AR) and mixed reality (MR) technologies in the field of chiropractic has been paid more and more attention. These technologies enable the operator to master the adjacent relationship of the anatomical structure in the manipulation area, display the deep anatomical structure without destroying the surface anatomical structure[6], and synchronize the manipulation operation with the acquisition of effect information[7]. Therefore, the application of VR in the clinical study of LPM has become the necessity of the development of the times.

2 Origin of VR technology and its application in medicine

VR originated in the United States in the 1960s and was born in a simulator designed for pilot training. It is a visual application technology that immerses users in a synthetic three-dimensional environment through a wearable screen[8]. This technology has the characteristics of autonomy, conception, multi-perception, immersion and interaction from the beginning[9-11]. In the 1990s, the VR technology was applied in the field of medical education and surgery, through the establishment of a virtual model of the human body in the computer and the realization of surgical preview on this basis[12]. FUJII *et al.*[13-14] used cystoscopy combined with single-incision laparoscopy to determine the extent of the tumor to achieve tumor resection, and the VR glasses worn by the operator during the operation clearly and synchronously displayed the target images taken by the two lenses. Chen Youzhi *et al.*[15] used Unreal Engine 4 as a template to input the problems such as pulse rate and blood pressure that easily occurred in surgery into the system to realize visualization, and later realized the prediction and disposal of simulation information through their self-developed tactile feedback gloves. VR is used as a distraction technique in the management of acute pain. Ahmadpour *et al.*[16] applied VR in the management of chronic pain, and displayed the induced information image on the window display interface to distract the patient's attention and induce the physiological changes of his sensitive nerves.

Received: July 24, 2024 Accepted: November 17, 2024
Supported by Zhoushan Young and Middle-aged Clinical Famous TCM Physician Project in 2024 (Zhoushan Finance and Social Security [2024] No.52).
* Corresponding author. E-mail: lvlijiang0288@163.com

3 Introduction of AR surgery

Since the introduction of VR technology, some people in the United States[17] have gained inspiration from daily operations, superimposed 2D or even 3D virtual images generated by computers on 2D real scenes, and strengthened them to achieve precise anatomical positioning in surgery[18-20]. In neurosurgery, Yavas *et al.* [21] used optical tracking cameras such as LIDAR and AR neuronavigation to track the nerve distribution in the surgical area, marked the surgical scene during the operation, and superimposed it with the surgical frame prepared before the operation, and found that the error was in the range of 0.5 - 3.5 mm. Harley *et al.* [22] developed a surgical navigation system, which installed the accessories of optical sensors on the shell of the micro projector, continuously transformed the matrix before operation to correct the spatial relationship between the pico-pro centers of the sensors and synchronized the virtual camera in the AR-SN platform to achieve synchronous tracking of multiple surgical instruments during the operation. Tests in human surgery showed that the application of the system could improve the accuracy of surgery to (0.55 ± 0.33) mm. Wang Qinghui *et al.* [23] developed an AR-based navigation system and applied it to the navigation system for minimally invasive spine surgery. They reconstructed the spine model and imported it into the navigation system after computing and storing the system before operation. The position information of the surgical instrument was captured by the optical tracker in real time during the operation and sent to the head mounted display (HMD) of the surgeon accordingly. After testing, the navigation system can reduce the error between the actual operation and the operation plan to 2.8 mm, which fully meets the requirements of clinical application.

4 Emerging of MR medicine

The ultimate development of information interaction technology must be to realize the synchronous enhancement of VR and AR, and to strengthen the bridge between them[12,24-25]. In the 1990s, Professor Steve of the University of Toronto in Canada put forward a clear concept of mediated reality, which is today's mixed reality (MR)[26]. The introduction of this theory enables medical researchers to carry out long-term observation in the real world and interact frequently with the virtual world[27]. Through the simulation of software and the assistance of HMD, it can provide medical students with fascinating learning experience such as 3D holography[25, 28-30], which is convenient for them to actively and completely contact the virtual surgical environment, and timely obtain the risk tips of the current operation in the real surgical operation (such as the hazards of radiation exposure or infection exposure[31]). Sufficient experience of the possible risks and the headset of the equipment can eliminate the diversion of attention caused by tension, so that young medical students can gain absolute confidence in the operation and shorten the operation time[28,32]. Stefan *et al.* [33] created a 3D-printed vertebral model using agar gel and projected it in the orientation of the C-arm of the X-ray through the MR navigation of the HMD, in this way, the surgical trainees were protected from radiation in a fairly realistic surgical environment[34]. Molina *et al.* [35] used MR navigation to resect the patient's L1 chordoma with an osteotome only under the guidance of the CT image of the holographic 2D axis. The operation preserved the integrity of the tumor resection, achieved perfect non-contact with the spinal cord around the tumor, and controlled the possible injury to the patient due to the severed nerve conduction. Through forming the standardized morphological imaging of complex tibial plateau fractures on the head-mounted display device using 3D modeling, David *et al.* [36] obtained more than 10 questionnaires of surgical entry strategy through navigation calculation and measurement, which provided reference for them to select the optimal scheme.

5 Clinical study of sagittal parameters of spine and pelvis

The pelvic sagittal parameters included pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS), and lumbar parameters included lumbar lordosis (LL), LL and PI matching, LL and SS matching. Through clinical studies, Jiyi *et al.* [37] found that the decrease of PI can cause low back pain. In the study of persistent low back pain caused by lumbar degenerative diseases, Yuan Jianjun *et al.* [38] found that PI was relatively constant and rarely changed in all spine-sagittal sequences, the change of PT was related to SS, PT parameters changed with the position of pelvis or spine[39-40], and the control of persistent low back pain was significantly related to the improvement of three angles. Through clinical research, Arija *et al.* [41] found that with the increase of age, the change of LL in women is more obvious than that in men. Yang Zexi *et al.* [42] found that the PI and PT of LDH patients below 35 years old were significantly increased, and LL and SS were significantly decreased compared with normal healthy young people. Pan Junjie *et al.* [43] found in the study of pelvic sagittal parameters of patients with single-segment lumbar spinal stenosis that the increase of PI was reflected in the impact on PT and SS, it not only changed the center of gravity of the body, but also adjusted the curvature of the lumbar spine. Guo Anna *et al.* [44] found that the change of LL accelerated the degeneration of lumbar intervertebral disc by indirectly increasing the shear force of the longitudinal axis of the lumbar spine.

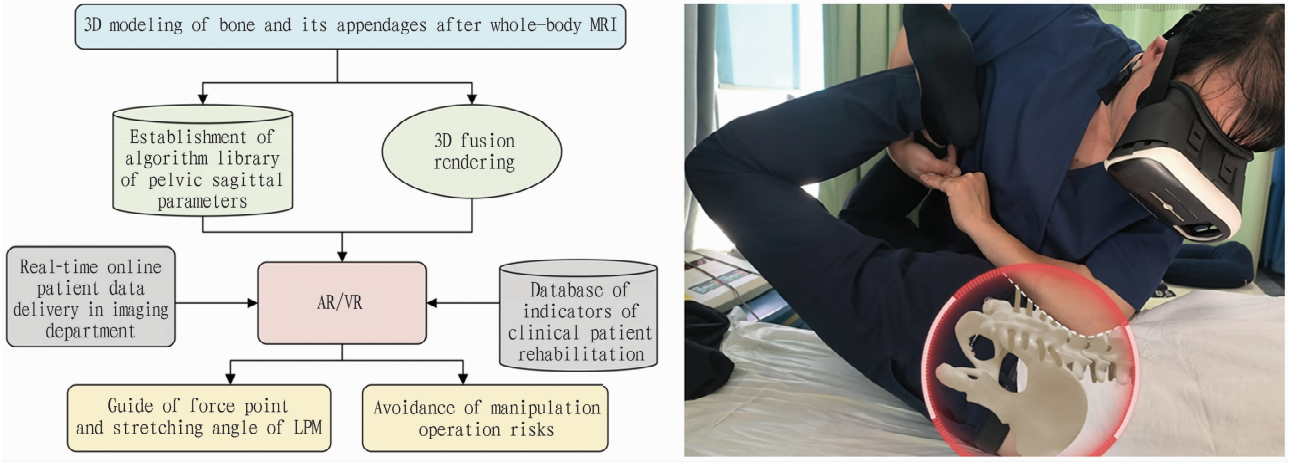
6 Combination of LPM and imaging medicine

The development of lever positioning manipulation has been closely linked with the development of spinal science. The school of famous physician Lu highly combined manipulation research with clinical imaging in promoting the mechanical characteristics of manipulation. Lu Senwei *et al.* [45] used Smatom Emotion-16CT to bind the volunteers to the lumbar visual field in a prone and backward extension position and applied manipulation mechanical test to determine the effect of manipulation on the function of the lumbar posterior joint of the subjects. It was found that the posterior

extension position induced by manipulation could cause the spatial changes of the superior and inferior articular process space in the L4-5 segment of LDH patients. Professor Lu Lijiang's team[46] used X-ray, CT and MRI imaging to measure spine-pelvic sagittal parameters in patients with LDH before using lever positioning manipulation (LPM), and found that the use of LPM can promote the restoration of overall pelvic balance. Zhang Haoyi *et al.* [47] found through X-ray fluoroscopy that lever positioning manipulation could significantly reduce the LL of the patient's lumbar spine, thus changing the anteversion of the pelvis. Xie Yunxing *et al.* [48] used Ferguson's method[49] to measure the lumbosacral angle on the lateral X-ray of the patient's thoracic spine during the treatment of LDH with this manipulation, and found that the use of manipulation effectively avoided the multiple transmission of force and promoted the recovery of lumbar curvature. Professor Lu Lijiang's team[3] additionally used X-ray fluoroscopy to measure the Cobb angle of thoracolumbar spine before lever positioning manipulation treatment for patients with LDH and thoracolumbar scoliosis, and found that the use of manipulation could reverse the patient's abnormal Cobb angle, thereby correcting vertebral rotation and pelvic tilt.

7 Development of lever positioning manipulation XR navigation

As a mature technology widely used in the field of spinal surgery, lever positioning manipulation can not be ignored in the relatively conservative non-surgical field of spinal health care. Drawing on the relatively rich experience in the medical field at home and abroad, Professor Lu Lijiang's team has focused on transplanting (Extended Reality, XR) navigation technology into their innovative planning in the treatment of LDH. The design requirements of the technology are in line with the actual operation of manipulation and the individualized consideration of patient treatment in terms of hardware and software configuration (Fig. 1). The design is based on the multiple problems that have been encountered and may be faced in the future in the clinical operation of the treatment of LDH since the generation of lever positioning manipulation, with modular layout and convenient intelligent response as the core, highlighting the characteristics of multidisciplinary comprehensive development. Considering that in the early stage of technology development, in order to save research and development costs, it is necessary to figure out how to select the key points in the design layout, and according to the needs of the development of the discipline market, leave enough space for the replacement of the next generation version, and develop applications in new application fields. Specifically, the design of hardware highlights the ability of HMD core processor to exchange and collate data, and the development of software highlights the interaction of clinical, rehabilitation and nursing.



NOTE A. LPM XR navigation setup process; B. The operator wears FMD and operates LPM under the guidance of XR navigation to treat LDH: The patient lies on his back, bends his hips and knees and crosses his lower limbs. Under the guidance of XR navigation, the doctor wears HMD to locate the patient's vertebral segment with the olecranon of one elbow, and holds the patient's ankles with both hands on the other side and pulls them backward and upward to drive the lumbar spine to the "trigger point", so as to pull them quickly with controlled force.

Fig. 1 LPM XR navigation establishment process and operation concept diagram

8 Discussion and prospects

As a hardware development with standard chiropractic navigation software, its program operation interface can visually present a complete state of spinal health or loss of health. Therefore, the image acquisition before 3D modeling should be based on the entity of these two types of individuals, so that the MRI images can be cut into 1 mm thin slices and saved in DICOM format[50]. Through software analysis and layer-by-layer superposition, the spatial scope of the skeleton and the system outside the skeleton is distinguished and marked with different colors. In order to facilitate the morphological judgment of clinical diagnosis and rehabilitation assessment, the complete digital construction of human skin and the rendering of simulated human gender characteristics are ideally completed on the basis of the wrapping of the core skeleton and

muscle of the motor system. The development of technology devices requires the ability to perceive and create virtual environments, separate from the physical environment. Therefore, it is necessary to use a large number of sensors such as sound and light in the hardware configuration to obtain information similar to human senses[51]. A high-definition 3D camera device (more than 1.3 million pixels) should be installed at the operation site to facilitate AR capture and comparison of the model database and intelligent modification to make the height of the generated virtual human close to the patient's physical appearance[22], and to standardize the shooting of the spatial angle of the patient's lower limbs raised with the operator's arm during the lever positioning treatment of LDH.

In order to make the AR system produce a meaningful expansion of the operation lever positioning in the manipulation treatment of LDH, the operation environment must provide a smooth network streaming media guarantee. The 3D digital human spine holographic image, the sagittal parameters of the patient's pelvis and the prediction information of the pressure difference between the inside and outside of the intervertebral disc should be superimposed and enlarged at any time and displayed in the corresponding playing area of the HMD with high quality. In software design, the rendering of AR should not only stay on the screen image, but also strengthen the operating environment in both touch and hearing. Visual rendering not only introduces virtual data into the DR environment or superimposes them mechanically on the HMD, but also enables the lever positioning manipulation operator to have a rich and enhanced perception of the patient's lumbar disc condition, spinal stability and comfort after treatment. During the operation of lever positioning manipulation for LDH treatment, advanced algorithms can be used to develop novel patterns of user information interaction, such as eyeglass or head gaze, voice commands, multimodal gesture input, body movement, or AR controller control. In order to improve the operation accuracy of lever positioning manipulation in the treatment of classified LDH, the extraction of realistic image data of patients such as CT and MRI by AR should be able to reconstruct their integrity in space. Besides, the corresponding pelvic number table is accurately given as an auxiliary operation medium for mechanical operation. Navigation should fully understand the material structure characteristics of spinal skeleton, intervertebral disc and paraspinal muscles, and capture the stress adjustment information of these structures due to spinal movement. In the process of manipulation operation, AR think tank should accurately prompt the position of the manipulation operator's elbow contact point according to the image and on-site judgment, and predict the patient's blood pressure, pulse, heart rate, respiration and pain threshold according to the data navigation. It can roughly judge the mechanical strain of the patient's lumbar intervertebral disc in the process of excessive lifting, and give the elbow tip force of the operator and prompt it in HMD in real time. In the development of HMD, it should increase the application of 3D holographic imaging technology, make interactive technology serve the operation of lever positioning thoroughly, and improve the application rate of manipulation from the perspective of scientific and technological innovation. In the process of using HMD, in order to facilitate the operator to obtain extremely high wearing comfort, the accurate measurement of the operator's visual distance and pupil distance by AR is also worth considering. By adjusting the viewing distance of 3D imaging, the operator's concern about the image blind area caused by myopia during manipulation can be reduced. In the future AR think tank configuration, efforts will be made to realize the information exchange between navigation and industry management departments, automatically expand the lever positioning manipulation operation path of LDH according to the long-term information backup expansion, and further deepen the concept of treatment path. The operation of the system should focus on its ability to resist electromagnetic interference and store operating memory in the event of power failure.

With the rapid development of computer information technology, medical technology has gradually become intelligent, precise and convenient[7]. From the application of XR technology in the field of global surgery, it is not difficult to see that although the digital human body is alive, there are still many uncertainties in the use of XR equipment and systems. Therefore, in the transplantation evaluation of technology application, it is necessary to examine a set of practical manipulation design suitable for lever positioning, especially for LDH in chiropractic treatment, from the aspects of electricity, information and algorithm. Based on the biological characteristics of chiropractic, the application of information algorithm should use local modular expression to solve the problems that need to be dealt with as a whole. Software services should provide different lever positioning packages according to the clinical classification of lumbar intervertebral disc. According to the strict standardization of LDH diagnosis and treatment standards by the World Health Organization, the generation update of navigation software should constantly adapt to the new clinical needs in practical application. In the early stage of technology development, animal experiments should be used to find out the problems that may occur in human use, and the algorithm and technical route should be adjusted in the later stage. The treatment of LDH by bar-positioning technology has gone through the era of physical and chemical experiments, the era of biomechanics, and is moving towards the era of information electrophysiology. As one of the chiropractic techniques, the lever positioning manipulation is quite demanding on the use of force. The movement of the fulcrum during the operation determines the change of the arm of force, so the force of manipulation during the operation must float accordingly, and this floating is still controlled by human beings. How to avoid the artificial floating error and navigate the clear experience in the use of the field of surgery, it is necessary to endow the software with a new mission in the field of chiropractic development, and also bring a new spring for the development of the discipline in the middle of the twenty-first century.

References

[1] ZHOU YF. Tui Na manual science for higher education in traditional Chinese medicine industry[M]. Beijing: China Traditional Chinese Medicine Press, 2021: 231 - 233. (in Chinese).

[2] LU LJ, MAO LY, LI JH, *et al.* Lever positioning manipulation combined with pulsed electric field on the analgesic effect of patients with lumbar

disc herniation and its influence on IL-1β and TNF-α[J]. China Journal of Orthopaedics and Traumatology, 2021, 34(8): 780 – 784. (in Chinese).
[3] LU LJ, LI JH, YANG C, *et al.* Clinical effect of lever positioning manipulation for lumbar disc herniation and its influence on Cobb angle[J]. China Journal of Orthopaedics and Traumatology, 2021, 34(1): 86 – 90. (in Chinese).
[4] FENG Z, CHU ZQ. Lu Lijiang's experience in treating lumbar intervertebral disc herniation with five-step repositioning method[J]. Zhejiang Journal of Traditional Chinese Medicine, 2013, 48(3): 218. (in Chinese).
[5] GAO XF, LU LJ. Traditional Chinese medicine speciality therapy for spinal diseases[M]. Beijing: China Traditional Chinese Medicine Press, 2023: 143 – 148. (in Chinese).
[6] FAN LY, MA JY, ZHANG KF. Application and development of AR/VR technology in human anatomy teaching and operation training[J]. Science & Technology Review, 2020, 38(22): 31 – 40. (in Chinese).
[7] LI YD, LIU AF, ZHANG JT, *et al.* Application of VR, AR, and MR technologies in clinical teaching of orthopaedics[J]. Chongqing Medicine, 2021, 50(8): 1432 – 1434. (in Chinese).
[8] YEUNG AWK, TOSEVSKA A, KLAGER E, *et al.* Virtual and Augmented Reality Applications in Medicine: Analysis of the Scientific Literature [J]. Journal of Medical Internet Research, 2021, 23(2): e25499.
[9] MCKNIGHT RR, PEAN CA, BUCK JS, *et al.* Virtual reality and augmented reality: Translating surgical training into surgical technique[J]. Current Reviews in Musculoskeletal Medicine, 2020, 13(6): 663 – 674.
[10] SAZID H, ALEX M, DEVAN H, *et al.* Virtual and augmented reality in spine surgery: An era of immersive healthcare[J]. Cureus, 2023, 15 (8): e43964.
[11] Virtual Reality. Baidu Encyclopedia[EB/OL]. [2024-04-26]. https://baike. baidu. com/item/% E8% 99% 9A% E6% 8B% 9F% E7% 8E% B0% E5% AE% 9E/207123? fr = ge_ala. (in Chinese).
[12] VENKATESAN M, MOHAN H, RYAN JR, *et al.* Virtual and augmented reality for biomedical applications[J]. Cell Reports Medicine, 2021, 2(7): 100348.
[13] FUJII Y, KIHARA K, YOSHIDA S, *et al.* A three-dimensional head-mounted display system (RoboSurgeon system) for gasless laparo-endoscopics single-portpartial cystectomy[J]. Wideochirurgia I Inne Techniki Maloinwazyjne, 2014, 9(4): 638 – 643.
[14] WANG WD, ZHANG YS. Application of head-mounted VR glasses in teaching urology 3D visualisation surgery[J]. Journal of Modern Medicine & Health, 2023, 39(21): 3752 – 3755. (in Chinese).
[15] CHEN YZ, FAN XZ. Design of emergency training system for lower limb fracture surgery based on virtual reality technology[J]. Packaging Engineering, 2021, 43(2): 152 – 158. (in Chinese).
[16] AHMADPOUR N, RANDALL H, CHOKSI H, *et al.* Virtual Reality interventions for acute and chronic pain management[J]. The International Journal of Biochemistry & Cell Biology, 2019, 9(114): 105568.
[17] Johns Hopkins completes first US spinal fusion with AR image guidance [EB/OL]. (2020-06-12) [2024-04-28]. https://baijiahao. baidu. com/s? id = 1669271810170607812&wfr = spider&for = pc. (in Chinese).
[18] WU HB, XU Y, YU S, *et al.* Review of projection display technology in augmented reality surgical navigation system[J]. Optics and Precision Engineering, 2021, 36(7): 161 – 165. (in Chinese).
[19] ZHANG ZJ, TIAN Z, WEN J. Progress in the application of 3D visual reconstruction and AR surgical navigation technology in surgery[J]. Journal of Contemporary Urologic and Reproductive Oncology, 2023, 15 (5): 316 – 320. (in Chinese).
[20] JENNA S, MAHMOOD S, KONSTANTINOS S. Augmented Reality (AR) for surgical robotic and autonomous systems: State of the art, challenges, and solutions[J]. Sensors, 2023, 23: 6202.
[21] YAVAS G, CALISKAN KE, CAGLI MS. Three-dimensional-printed marker-based augmented reality neuronavigation: A newneuronavigation technique[J]. Neurosurg Focus, 2021, 51(2): E20.
[22] CHAN HHL, HAERLE SK, DALY MJ, *et al.* An integrated augmented reality surgical navigation platform using multi-modality imaging for guidance[J]. PLoS ONE, 2021, 16(4): e0250558.
[23] WANG QH, ZHAO KH, SONG GL, *et al.* Augmented reality-based navigation system for minimally invasive spine surgery[J/OL]. Robotics, [2023-02-24]. https://doi. org/10. 13973/j. cnki. robot. 220300. (in Chinese).
[24] CHYTAS D, NIKOLAOU VS. Mixed reality for visualization of orthopedic surgical anatomy[J]. World Journal of Orthopedics, 2021, 12(10): 727 – 731.
[25] WONG KC, SUN YE, KUMTA SM. Review and Future/potential application of mixed reality technology in orthopaedic oncology[J]. Orthopedic Research and Reviews, 2022, 16(14): 169 – 186.
[26] STEVE M. Mediated reality[EB/OL]. (1998-02-14)[2024-05-05]. Http://www. researchgate. net/publication/279409_Medated_reality'.
[27] WANG HW, WANG XX, YAN R, *et al.* A review of mixed reality technology in nursing[J]. Journal of Nursing Science, 2022, 37(11): 110 – 113. (in Chinese).
[28] TADATSUGU M, TAKAOMI K, HIROHITO H, *et al.* XR(Extended Reality: Virtual Reality, Augmented Reality, Mixed Reality) technology in spine medicine: Status quo and quo vadis[J]. Journal of Clinical Medicine, 2022, 11(2): 470.
[29] WONG KC, SUN EY, WONG IOL, *et al.* Mixed reality improves 3D visualization and spatial awareness of Bone tumors for surgical planning in orthopaedic oncology: A proof of concept study[J]. Orthopedic Research and Reviews, 2023, 31(15): 139 – 149.
[30] ZHANG YM, LIU SL, FENG QM, *et al.* Applications of naked-eye 3D display technology in medical field[J]. Chinese Journal of Medical Instrumentation, 2024, 48(1): 40 – 56.
[31] FIANI B, JENKINS R, SIDDIQI I, *et al.* A socioeconomic impact of COVID-19 on spinal instrumentation companies in the era of decreased elective surgery[J]. Cureus, 2020, 12: e9776.
[32] MATSUKAWA K, YATO Y. Smart glasses display device for fluoroscopically guided minimally invasive spinal instrumentation surgery: A preliminary study[J]. Journal of Neurosurgery: Spine, 2020, 34(1): 150 – 154.
[33] STEFAN P, PFANDLER M, WUCHERER P, *et al.* Team training and assessment in mixed reality-based simulated operating room: Current state of research in the field of simulation in spine surgery exemplified by the ATMEOS project[J]. Unfallchirurg, 2018, 121: 271 – 277.
[34] YUK FJ, MARAGKOS GA, SATO K, *et al.* Current innovation in virtual and augmented reality in spine surgery[J]. Annals of Translational Medicine, 2021, 9(1): 94.
[35] MOLINA CA, DIBBLE CF, LO SL, *et al.* Augmented reality-mediated stereotactic navigation for execution of en bloc lumbar spondylectomy osteotomies[J]. Journal of Neurosurgery: Spine, 2021, 34(5): 700 – 705.
[36] BITSCHI D, FÜRMETZ J, GILBERT F, *et al.* Preoperative mixed-reality visualization of complex tibial plateau fractures and its benefit compared to CT and 3D printing[J]. Journal of Clinical Medicine, 2023, 12 (5): 1785.
[37] LIU JY, HUANG PZ, JIANG GW, *et al.* Spinal-pelvic sagittal parameters in patients with gluteal muscle contracture: An imaging study[J]. PeerJ, 2022, 15(10): e13093.
[38] YUAN JJ, LI G, ZHANG Q, *et al.* The relationship between spinal-pelvic sagittal parameters and persistent low back pain after degenerative lumbar disease surgery[J]. Journal of Practical Orthopaedics, 2024, 30 (2): 115 – 152. (in Chinese).
[39] ZHANG C, MA C, CHEN T. Relationship between degenerative lumbar

spondylolisthesis and spinopelvic sagittal parameters[J]. Journal of Xuzhou Medical University, 2021, 41(1): 35-38. (in Chinese).
[40] MA JF. Correlation of spine-pelvis sagittal position parameters with surgical efficacy and postoperative low back pain after lumbar spine fusion [D]. Tianjin: Tianjin Medical University, 2020. (in Chinese).
[41] ARIJA J, PHILIPP S, ESRA A, *et al.* Relation between sagittal pelvic and thoracolumbar parameters in supine position - Pelvic parameters and their predictive value for spinal Cobb angles[J]. Brain Spine, 2024, 5(4): 102779.
[42] YANG ZX, YU M, ZHAO WK, *et al.* The characteristics of sagittal alignment of spine-pelvis in lumbar disc herniation in patients under 35 years old[J]. Chinese Journal of Minimally Invasive Surgery, 2023, 23(4): 272-275. (in Chinese).
[43] PAN JJ, LI GJ, HAO WQ, *et al.* A study of the changes in spinal-pelvic sagittal parameters before single-segment LSS and analysis of the factors influencing them[J]. Zhejiang Journal of Traumatic Surgery, 2023, 28(2): 240-242. (in Chinese).
[44] GUO AN, CHEN SQ, YAN ZH, *et al.* Correlation between Sagittal Spino-pelvic Alignment and Lumbar Disc degeneration in Asymptomatic Chinese Adults[J]. Journal of Medical Research, 2021, 50(6): 136-149. (in Chinese).
[45] LU SW, LU LJ, WANG XD, *et al.* Biomechanical study on the effect of simulated lever positioning manipulation on the stability of lumbar posterior joint[J]. Zhejiang Journal of Traditional Chinese Medicine, 2015, 50(4): 245-246. (in Chinese).
[46] LU LJ, XIE YX, CHEN YF, *et al.* A clinical research on the effect and the influence on pelvic parameters of lever positioning manipulation in treating patients with lumbar disc herniation[J]. Journal of Zhejiang Chinese Medical University, 2019, 43(7): 640-644. (in Chinese).
[47] ZHANG HY, MAO YL, LU LJ. Research on the changes of sagittal parameters of spine and pelvis in patients with adolescent idiopathic scoliosis based on lever positioning manipulation[J]. China Modern Doctor, 2022, 60(4): 147-150. (in Chinese).
[48] XIE YX, LU LJ, DU HG, *et al.* A clinical study of lever positioning manipulation for treatment of lumbar disc herniation[J]. The Journal of Traditional Chinese Orthopedics and Traumatology, 2021, 33(3): 1-5. (in Chinese).
[49] MOU CL, SHEN XN, LI GF. Therapeutic effect of Chinese orthopaedic manipulation combined with external application of traditional Chinese medicine to improve lumbar curvature in lumbar intervertebral disc herniation[J]. Lishizhen Medicine and Materia Medica Research, 2020, 31(5): 1179-1183. (in Chinese).
[50] JIANG Q, DING Y, LIU JY, *et al.* Finite element simulation and biomechanical analysis of fully endoscopic precisely laminectomy decompression[J]. Chinese Journal of Tissue Engineering Research, 2020, 24(12): 1891-1896. (in Chinese).
[51] NAVAB N, MARTIN-GOMEZ A, SEIBOLD M, *et al.* Medical augmented reality: Definition, principle components, domain modeling, and design-development-validation process[J]. Journal of Imaging, 2022, 9(1):4.

(From page 106)

[2] LIU YM, SHAWUTI YIKEMU. Uyghur Pharmacognosy[M]. Urumqi: Xinjiang Science and Technology Health Publishing House, 1999. (in Chinese).
[3] RUXIANRU MAIMITIMING. Application of rose in Uyghur medical treatment[J]. Journal of Medicine & Pharmacy of Chinese Minorities, 1999(3): 27. (in Chinese).
[4] State Administration of Traditional Chinese Medicine, Chinese Materia Medica Editorial Committee. Chinese Materia Medica (Volume 8)[M]. Shanghai: Shanghai Science and Technology Press, 1999. (in Chinese).
[5] LIU ZH, SAN CH, LU L, *et al.*. Rose essential oil of processing technology[J]. Farm Products Processing, 2006, 11(82): 75-77. (in Chinese).
[6] XIAO ZP, WU HK, WU T, *et al.* Kaempferol and quercetin flavonoids from Rosa rugosa[J]. Chemistry of Natural Compounds, 2006, 42(6): 736-737.
[7] OLECH M, PIETRZAK W, NOWAK R. Characterization of free and bound phenolic acids and flavonoid aglycones in *Rosa rugosa* Thunb. leaves and achenes using LC-ESI-MS/MS-MRM methods[J]. Molecules, 2020, 25(8): 1804.
[8] LIU YM, LIU KF. Study of chemical components of rose essential oil grown in Xinjiang[J]. Fine Chemicals, 2002,19(7): 388-389, 405. (in Chinese).
[9] QIAN ZY, LI J, WANG C. Analysis of volatile compounds from flower of *Rosa rugosa* Thunb with solid phase microextraction by GC/MS[J]. Modern Scientific Instruments, 2013, 30(6): 108-111. (in Chinese).
[10] CHEN GL, CHEN SG, XIAO Y, *et al.* Antioxidant capacities and total phenolic contents of 30 flowers[J]. Industrial Crops and Products, 2018, 111: 430-445.
[11] HUANG WS, MAO SQ, ZHANG LQ, *et al.* Phenolic compounds, antioxidant potential and antiproliferative potential of 10 common edible flowers from China assessed using a simulated digestion-dialysis process combined with cellular assays[J]. Journal of the Science of Food and Agriculture, 2017, 97(14): 4760-4769.
[12] SHAO DW. Study on the antioxidations capcity of Rosa rugosa flower bud[D]. Tai'an: Shandong Agricultural University, 2008. (in Chinese).
[13] DU J. Comprehensive utilization of rose oil post-products[D]. Urumqi: Xinjiang Agricultural University, 2006. (in Chinese).
[14] BAI WF. Study on the extraction and activity of rose polysaccharide [D]. Jinan: Shandong Institute of Light Industry, 2010. (in Chinese).
[15] YU F. Extraction, analysis and application of rose essential oil[D]. Nanchang: Nanchang University, 2011. (in Chinese).
[16] HE X, HAN N. Extraction of flavones from rose by supercritical CO_2 extraction method and research on its healthy function[J]. Journal of Anhui Agricultural Sciences, 2009(26): 12699-12700. (in Chinese).
[17] HE X. Research on the new process of extraction of rose essential oil and related animal experiments[D]. Jinan: Shandong Normal University, 2002. (in Chinese).
[18] LONG G. Toxicology and anti-aging efficacy of rose water extract[D]. Guangzhou: South China Normal University, 2005. (in Chinese).