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Original article

An Innovative Method for the Treatment of Degenerative Lumbar Spine Disorders: Lumbar Interbody Fusion Using Autologous Stromal Vascular Fraction

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Abstract

This study aimed to evaluate clinical and radiological outcomes of lumbar interbody fusion using a titanium cage filled with autologous stromal vascular fraction of adipose tissue in degenerative lumbar spine disease.

Thirty patients with degenerative lumbar spine disease unresponsive to conservative treatment underwent posterior or transforaminal lumbar interbody fusion with decompression, transpedicular fixation and implantation of a porous titanium interbody cage packed with autologous bone and a cell based biocomposite hydrogel containing stromal vascular fraction of adipose tissue. Pain in the lumbar region and lower limbs was assessed with a visual analogue scale, and disability with the Oswestry Disability Index before surgery and at one, three to four and twelve months after surgery. Radiological evaluation included radiography, computed tomography densitometry of the interbody region and grading of fusion according to the Tan classification at twelve months.

No intraoperative neurological or implant related complications occurred, and wound healing was uneventful. During twelve months of follow up there was a marked reduction in lumbar and leg pain and disability, with most patients improving from severe to minimal functional impairment. Computed tomography showed a progressive increase in bone density in the cage region, indicating maturation of the interbody bone block. At twelve months, complete interbody fusion was achieved in seventy per cent of patients, partial fusion in twenty per cent and monopolar pseudarthrosis in ten per cent; no bipolar pseudarthrosis was observed.

Lumbar interbody fusion using a porous titanium cage combined with autologous stromal vascular fraction of adipose tissue provided reliable stabilization, a high rate of fusion and clinically meaningful improvement in pain and function during the first postoperative year.

Keywords: lumbar, intervertebral disc degeneration, spinal fusion, titanium, adipose tissue, stromal vascular fraction, mesenchymal stem cells.

1. Introduction

Degenerative diseases of the lumbar spine and the resulting low back pain remain one of the leading causes of temporary work incapacity and disability worldwide. According to the Global Burden of Disease 2021 study, low back pain is consistently among the main causes of years lived with disability in the working-age population and shows an upward trend with population ageing [1]. Despite advances in conservative management, a considerable proportion of patients with severe pain, neurological deficit and segmental instability ultimately require surgical intervention aimed at decompression of neural structures and stabilization of the spine [2].

Posterior and transforaminal lumbar interbody fusion (PLIF/TLIF) are widely used techniques for the surgical treatment of degenerative lumbar spine disorders [3]. However, even with modern instrumentation and meticulous surgical technique, the incidence of pseudarthrosis remains clinically significant, ranging from 5% to 35%, particularly in multilevel fusions and in patients with risk factors such as advanced age, smoking, osteoporosis and a history of previous surgery [4]. Pseudarthrosis is associated with persistent or recurrent pain, reduced quality of life and a higher need for revision procedures, underscoring the importance of strategies to improve the rate and quality of bony fusion.

A key component of interbody fusion is the cage implant, which must provide adequate primary mechanical stability and a favorable environment for osteogenesis [5,6]. Titanium and polyetheretherketone (PEEK) are the most commonly used materials, each with specific advantages and limitations [5,6]. Solid titanium is strong and biocompatible but has a high elastic modulus and pronounced stress shielding, leading to a mismatch with cancellous bone [6]. PEEK more closely approximates bone in elastic modulus and produces fewer imaging artefacts on CT and MRI, but is bioinert and does not support direct bone–implant contact [7,8]. Recent clinical studies and meta-analyses have shown that titanium cages may achieve higher fusion rates than PEEK with comparable clinical outcomes [5,9].

The development of three-dimensional (3D) printed porous titanium cages with a trabecular architecture mimicking cancellous bone represents an important advance. Such designs reduce the effective elastic modulus, improve load distribution and provide an extensive osteoconductive surface for bone ingrowth [10]. Liu S.S. et al. demonstrated that 3D-printed porous titanium implants in interbody fusion are associated with low rates of cage subsidence, high fusion rates and improved clinical and functional outcomes [11].

In parallel, biological augmentation of fusion using cell-based technologies has gained increasing attention [12]. Mesenchymal stem cells (MSCs) are among the most promising tools in regenerative orthopaedics and spine surgery [13]. They can be harvested from bone marrow, adipose tissue and other sources, are multipotent, exert pronounced paracrine effects, modulate inflammation and stimulate osteogenesis [14]. Experimental and clinical studies have shown that adding MSCs to bone grafts or synthetic osteoconductive matrices can enhance the rate and quality of fusion [15], and long-term follow-up data support the safety and sustained efficacy of autologous MSCs in spinal fusion [16].

Adipose tissue has emerged as a convenient, minimally invasive source of stromal-vascular fraction (SVF) containing a population of MSCs [17]. SVF is a heterogeneous cell suspension including mesenchymal stromal cells, endothelial cells, pericytes, macrophages and other microenvironmental elements, rich in growth factors and cytokines. A key advantage of SVF is the possibility of intraoperative harvesting without a prolonged culture phase, which facilitates clinical translation [18]. Experimental studies, including the work of Roato I. et al., have demonstrated the pronounced osteogenic potential of SVF in combination with various bone matrices, with enhanced osteoblastic differentiation, mineralization and proangiogenic factor secretion compared with cultured adipose-derived MSCs [19].

In critical-size bone defect models, SVF combined with synthetic or ceramic carriers accelerates reparative osteogenesis and improves the structural organization of newly formed bone, achieving results comparable to autologous bone grafting [20]. Recent reviews emphasize SVF as a promising component of tissue-engineered constructs for bone and cartilage regeneration [21].

This study aims to evaluate the effectiveness of lumbar interbody fusion using a custom-made trabecular titanium cage filled with autologous stromal-vascular fraction of adipose tissue containing mesenchymal stromal cells.

2. Materials and methods

This work was carried out at the National Scientific Center for Traumatology and Orthopedics named after Academician Batpenov N.D.

The analysis included 30 patients with degenerative-dystrophic diseases of the lumbar spine who underwent surgical treatment using a trabecular titanium interbody cage in combination with cell technologies.

Ethical considerations

The study was conducted in accordance with the ethical principles set forth in the Declaration of Helsinki (1964) and its subsequent revisions. The study protocol was reviewed and approved by the local ethics committee (protocol No. 2/2 of July 19, 2023). Written informed consent was obtained from all patients prior to their inclusion in the study. Patients were provided with comprehensive information about the objectives of the study, the nature of the planned interventions, the possible risks, and their right to withdraw from participation at any time without prejudice to their future medical care. All study participants were insured for the entire observation period.

The criteria for inclusion in the study were:

-Signs of instability of the spinal motor segment;

-Spondylolisthesis;

-Spinal canal stenosis;

-Patients with recurrent intervertebral disc herniation;

-Ineffectiveness of conservative treatment;

-Neurological symptoms;

-Stage of intervertebral disc degeneration according to the Pfirmann III–V classification [22].

-Patient age between 30 and 70 years;

-Written consent of the patient to participate in the study.

The exclusion criteria were:

-Patient age under 30 and over 70 years;

-Infectious process at the site of the proposed surgical intervention;

-History of mental illness;

-Pregnancy;

-Written refusal to participate in the study.

Characteristics of the clinical status and medical history of patients

Analysis of the medical history revealed that all patients (n=30) had suffered from chronic pain syndrome in the lumbar region for a long time. Most patients had pronounced radicular pain syndrome with irradiation to one or both lower limbs; a significant proportion of patients complained of numbness, paresthesia, and decreased sensitivity in areas corresponding to the innervation of the affected roots. Eight patients (n=8) had a history of previous surgery to remove an intervertebral disc herniation at this level, and therefore the current surgical treatment was of a revision nature. Some patients had widespread comorbidities, including hypertension, ischemic heart disease, osteoarthritis of the large joints, type 2 diabetes mellitus, chronic gastritis, and chronic bronchitis.

All patients underwent a comprehensive preoperative examination:

-Clinical and neurological examination;

-X-ray and functional spondylography of the lumbar spine (assessment of instability, intervertebral space height);

-MRI of the lumbar spine (degree of disc degeneration according to Pfirrmann, changes in the endplates according to Modic [23], presence of stenosis according to Schizas [24];

-CT scan to clarify bone anatomy and subsequent objectification of bone block formation;

-Densitometry to assess bone mineral density;

-Standard list of laboratory examination methods.

Preparation of the cellular component of therapy

Adipose tissue was harvested from the anterior abdominal wall under local anesthesia using the liposuction technique described by Zuk P.A. et al. [25]. The lipoaspirate obtained was placed in sterile containers and, in compliance with the temperature regime, delivered to the National Biotechnology Center LLP for further cell processing.

The stromal-vascular fraction (SVF) was obtained from adipose tissue by combined enzymatic and mechanical processing, after which the cell suspension was washed and further cultured under standard incubation conditions. The biocomposite hydrogel (HCF) was formed according to a standardized protocol [26] based on heparin-conjugated fibrinogen, fibrinogen, aprotinin, thrombin, and calcium chloride. The resulting cell-matrix composite, including SVF and HCF, was then transported back to the trauma center.

Surgical technique

All interventions were performed in the operating room under endotracheal anesthesia using intraoperative navigation and CT control.

The main stages of the operation were as follows:

1. *Posterior approach (TLIF/PLIF)*: midline incision, layer-by-layer dissection of soft tissues, skeletonization of spinous processes, arches, and articular processes.

2. *Transpedicular fixation*: installation of a reference frame, formation of channels and insertion of transpedicular screws under the control of a navigation system and O-arm, followed by the installation of rods at the final stage.

3. *Decompression:* bilateral laminectomy and facetectomy with revision of the dura mater and nerve roots, removal of hypertrophied yellow ligament.

4. *Microdiscectomy*: opening of the fibrous ring, removal of hernated material, thorough curettage of the intervertebral space with preparation of the intervertebral bed.

5. *Cage preparation*: filling of the trabecular titanium cage with a mixture of autogenous bone and biocomposite hydrogel with CSP.

6. *Implant placement*: placement of the cage in the prepared intervertebral bed with restoration of disc height and segmental lordosis; final fixation of the rods and verification of the correct placement of the structure using an O-arm.

7. *Completion*: hemostasis, drainage placement, layer-by-layer wound closure, application of an aseptic dressing.

Patients were mobilized within 12 to 24 hours after surgery in a removable orthopedic corset and with the use of prophylactic measures against thromboembolic complications.

3. Results

Postoperative period

No intraoperative complications associated with damage to the dura mater or nerve structures were noted. Postoperative wounds in all patients healed by primary tension, and no signs of purulent-inflammatory complications were recorded. Early mobilization was achieved in all patients within the specified time frame; most tolerated verticalization satisfactorily, with a gradual expansion of their range of motion.

Pain syndrome dynamics

Clinical outcomes were assessed using a visual analog pain scale (VAS) for the lumbar spine and lower extremities, as well as the Oswestry Disability Index (ODI) in the preoperative period and 1, 3–4, and 12 months after the intervention. Before the operation, the VAS values in the lower back and legs corresponded to severe pain syndrome, but already 1 month after the operation, a significant decrease in pain indicators was noted, accompanied by a decrease in the need for analgesics and improved tolerance of physical activity (Table 1). The decrease in VAS (for the back and legs) and ODI at all observation periods compared to baseline values was statistically significant (in all cases $p<0.001$).

Table 1 - Dynamics of clinical indicators in patients of the main group

Indicator	Before surgery	1 month	3–4 months	12 months	P value
VAS, back (points)	8,2 ± 0,77	3,8 ± 1,06	2,10 ± 1,17	1,10 ± 1,12	p<0,001
VAS, leg (points)	5,15 ± 1,93	1,20 ± 1,28	0,55 ± 0,83	0,25 ± 0,55	p<0,001
ODI, %	68,15 ± 11,26	31,80 ± 8,53	18,30 ± 7,41	8,50 ± 7,02	p<0,001

Radiological examination methods

X-ray

According to serial control X-rays taken at all observation periods, the intervertebral cage was correctly positioned without signs of displacement, subsidence, or damage to the metal structure in all patients evaluated (Figure 1).

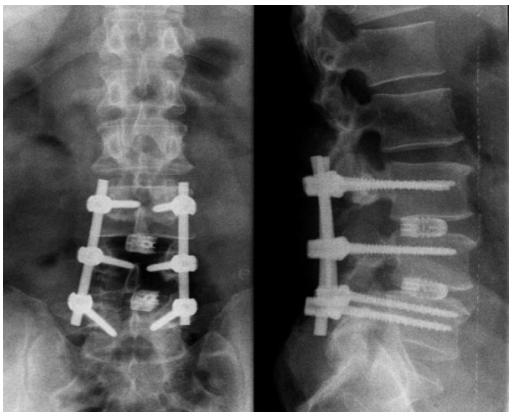

Figure 1 – Control X-ray of the lumbar spine in two projections after installation of a trabecular cage with cells

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Computed tomography and Hounsfield unit analysis. Osteointegration was assessed based on CT results using a standardized circular region of interest (ROI) with a diameter of 30 pixels located in the lumen of the trabecular cage (Figure 2). A consistent increase in X-ray density (in Hounsfield units, HU) was observed over time, indicating active formation and maturation of the interbody bone block.

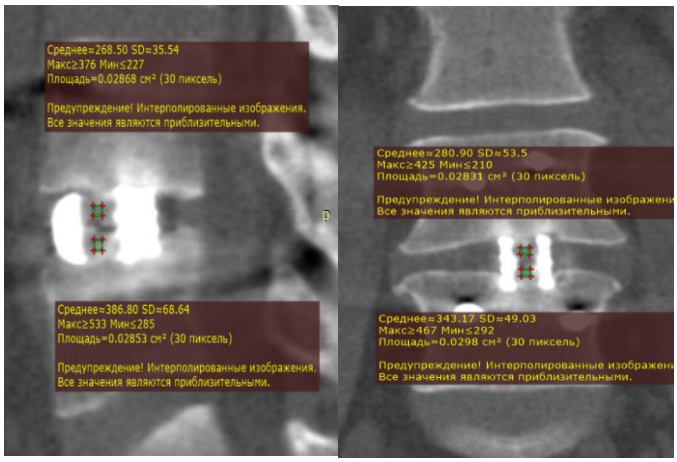

Figure 2 - CT densitometry 4 months after surgical treatment in the trabecular cage area: measurement of X-ray density (HU) in standardized ROIs with an area of 30 pixels in the cranial and caudal parts of the interbody block

According to CT densitometry data (Table 2), a gradual increase in bone X-ray density was observed in the trabecular cage area. The mean HU values increased from 424.7 ± 108.5 after 3–4 months to 522.5 ± 128.6 after 6 months and reached 586.3 ± 137.5 by the 12th month of observation ($p<0.001$). This trend reflects the progressive consolidation of the bone matrix within the cage and adjacent endplates and indicates the progressive formation and maturation of the interbody bone block.

Table 2 - Trends in X-ray density (HU) in the trabecular cage area

Observation period	HU units	P value
3–4 months	424.7 ± 108.5	p<0.001
6 months	522.5 ± 128.6	p<0.001
12 months	586.3 ± 137.5	p<0.001

Assessment of the degree of spondylodesis according to the Tan G.H. classification 12 months after surgery (Table 3) showed that complete bone fusion was achieved in most patients: grade 1 was recorded in 21 patients (70%) [27]. Partial fusion (grade 2) was noted in 6 patients (20%), while signs of monopolar pseudoarthrosis (grade 3) were found in only 3 patients (10%) (Figure 3)

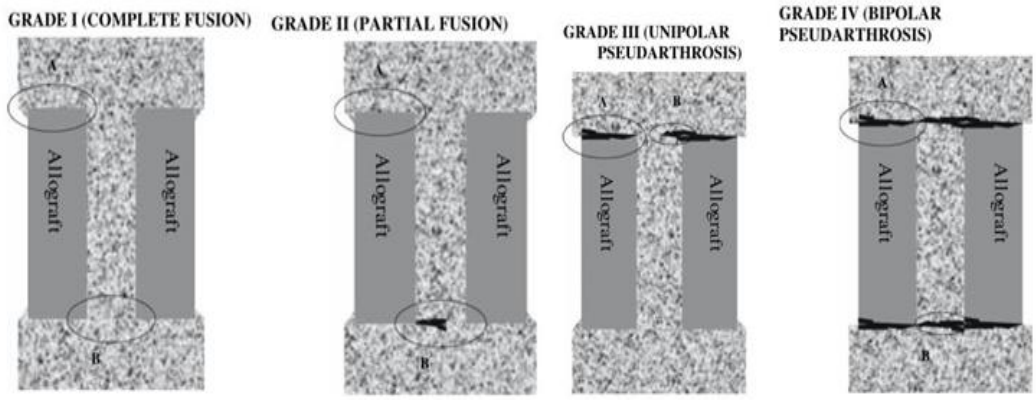

Figure 3 - Classification of interbody block according to Tan G.H.

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No cases of severe bipolar pseudoarthrosis (4th degree) were recorded. The data obtained collectively confirm the high effectiveness of the interbody spondylodesis technology under consideration, using a trabecular cage and cell technologies (Table 3).

Table 3 - Distribution of patients by degree of spondylodesis formation according to Tan G.H. after 12 months

Degree according to Tan G.H.	Characteristic	Number of patients (n=)
Grade 1	Complete fusion	n=21 (70%)
Grade 2	Partial fusion	n=6 (20%)
Grade 3	Monopolar pseudoarthrosis	n=3 (10%)
Grade 4	Bipolar pseudoarthrosis	n=0

Most patients had Tan grade 1, which corresponds to complete formation of the interbody bone block; the proportion of pseudoarthrosis (grades 3–4) was minimal (Figure 4).

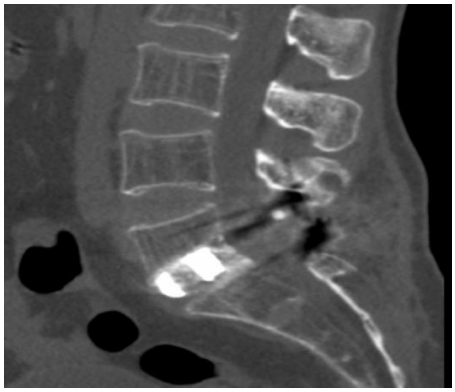

Figure 4 – Control CT scan of a 57-year-old female patient 12 months after surgery with trabecular cage implantation and bone block formation

Laboratory research methods

During dynamic observation, all n=30 patients underwent standard laboratory monitoring of peripheral blood and biochemical parameters to assess their general condition and rule out signs of inflammatory or metabolic complications. The analysis included determination of hemoglobin, erythrocyte, leukocyte, and ESR levels, as well as biochemical parameters such as glucose, creatinine, total protein, liver transaminase activity (ALT, AST), and C-reactive protein.

Throughout the observation period, the laboratory values of most patients remained within the reference ranges, indicating the absence of a pronounced systemic inflammatory response and a favorable postoperative course. Minor deviations in individual parameters noted in the early postoperative period were transient and normalized by the time of discharge or subsequent follow-up examinations.

4. Discussion

The results demonstrate that the use of a trabecular titanium cage filled with autologous stromal-vascular fraction (SVF) of adipose tissue containing MSCs provides a marked clinical and radiological improvement already during the first year of observation. There was a significant reduction in pain intensity according to the VAS in both the lumbar region and the lower extremities, as well as a reduction in disability according to the ODI from severe to minimal values; the differences compared to preoperative values were statistically significant at all observation periods ($p<0.001$).

The high frequency of interbody bone block formation in our series is confirmed both by CT densitometry data (sequential increase in HU in the cage area) and by the distribution of fusion grades according to Tan: most patients had grade 1 fusion, and there were no cases of severe pseudoarthrosis. Similar trends have been described in clinical studies comparing 3D-printed titanium and PEEK cages, where porous titanium structures demonstrate comparable or

higher fusion rates while maintaining clinical efficacy [28]. These data suggest that the trabecular architecture of the implant with optimized porosity does indeed create more favorable mechanical and osteoconductive conditions for bone regeneration.

An important feature of the presented work is the use of autologous fat tissue SFB as a biological enhancer of interbody spondylodesis. Experimental and preclinical models have shown that applying SFB to porous or ceramic bone matrices enhances osteogenic differentiation, mineralization, and vascular response, leading to more complete and structurally mature bone repair compared to a single carrier or isolated cultured adipose MSCs [29]. Studies on the use of MSCs and their derivatives in spondylodesis (including genetically modified cells and extracellular vesicles) show that cellular and paracrine mechanisms can improve fusion rates and the quality of the forming bone block [30]. Our data fit well with this concept: the combination of a trabecular titanium cage and MSCs rich in osteogenic and proangiogenic cells and growth factors forms a three-dimensional biologically active niche inside the cage, which probably accelerates the maturation of the interbody bone block and reduces the risk of pseudoarthrosis.

However, this study has a number of limitations. The small sample size and single-center nature of the observations reduce the statistical power and limit the possibility of a multifactorial analysis of the influence of concomitant conditions (osteoporosis, revision surgery, smoking, etc.) on treatment outcomes. The absence of a parallel control group using a similar trabecular cage without a cellular component does not allow us to quantitatively assess the contribution of SVF to the improvement of fusion rates and clinical outcomes; in fact, we compare the obtained data mainly with literature series. Finally, the observation period, limited to 12 months, is sufficient for a primary assessment of fusion, but does not provide complete information about the durability of the interbody block and the frequency of late complications.

Nevertheless, the combination of the results obtained allows us to consider biologically enriched interbody spondylodesis using a trabecular titanium cage and autologous stromal vascular fraction of adipose tissue as a safe and potentially more effective technology for the surgical treatment of degenerative diseases of the lumbar spine.

6. Conclusions

The results of this study demonstrate that the combination of a trabecular titanium cage and cell technologies provides both reliable mechanical stabilization and pronounced stimulation of bone regeneration in the interbody spondylodesis zone. During 12 months of observation, most patients experienced a significant reduction in pain, improved functional status, and the formation of a complete interbody bone block, as confirmed by an increase in HU values and the predominance of 1st degree fusion according to Tan G.H.

The data obtained are consistent with the concept of biologically “enriched” spondylodesis, in which porous titanium serves as an osteoconductive scaffold, and SVF is a source of cellular and humoral factors that enhance osteogenesis and angiogenesis. At the same time, the limited sample size and the lack of comparison with alternative cage options and biological materials do not allow us to draw definitive conclusions about the superiority of this technique. A promising direction for further research would be a direct comparison of this technology with traditional PEEK and titanium cages without a cellular component in randomized clinical trials.

Conflict of Interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

1. Zhang, C., Lv, B., Yi, Q., Qiu, G., & Wu, F. (2025). Global, regional, and national burden of low back pain in working-age population from 1990 to 2021 and projections for 2050. Frontiers in Public Health, 13, 1559355. https://doi.org/10.3389/fpubh.2025.1559355

2. Wu, P. H., Kim, H. S., & Jang, I. T. (2020). Intervertebral disc diseases PART 2: a review of the current diagnostic and treatment strategies for intervertebral disc disease. International journal of molecular sciences, 21(6), 2135. https://doi.org/10.3390/ijms21062135

3. Mobbs, R. J., Phan, K., Malham, G., Seex, K., & Rao, P. J. (2015). Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. Journal of spine surgery, 1(1), 2. https://doi.org/10.3978/j.issn.2414-469X.2015.10.05

4. Boonsirikamchai, W., Wilartratsami, S., Ruangchainikom, M., Korwutthikulrangsri, E., Tongsai, S., & Luksanapruksa, P. (2024). Pseudarthrosis risk factors in lumbar fusion: a systematic review and meta-analysis. BMC musculoskeletal disorders, 25(1), 433. https://doi.org/10.1186/s12891-024-07531-w

5. Tan, J. H., Cheong, C. K., & Hey, H. W. D. (2021). Titanium (Ti) cages may be superior to polyetheretherketone (PEEK) cages in lumbar interbody fusion: a systematic review and meta-analysis of clinical and radiological outcomes of spinal interbody fusions using Ti versus PEEK cages. European Spine Journal, 30(5), 1285-1295. https://doi.org/10.1007/s00586-021-06748-w

6. Patel, N. A., O'Bryant, S., Rogers, C. D., Boyett, C. K., Chakravarti, S., Gendreau, J., ... & Pham, M. H. (2023). Three-dimensional-printed titanium versus polyetheretherketone cages for lumbar interbody fusion: a systematic review of comparative in vitro, animal, and human studies. Neurospine, 20(2), 451. https://doi.org/10.14245/ns.2346244.122

7. Mobbs, R. J., Amin, T., Phan, K., Al Khawaja, D., Choy, W. J., Parr, W. C., ... & Walsh, W. R. (2022). Standalone titanium/polyetheretherketone interbody cage for anterior lumbar interbody fusion: Clinical and radiological results at 24 months. Journal of Craniovertebral Junction and Spine, 13(1), 42-47. https://doi.org/10.4103/jcvjs.jcvjs_133_21

8. Kurtz, S. M., & Devine, J. N. (2007). PEEK biomaterials in trauma, orthopedic, and spinal implants. Biomaterials, 28(32), 4845-4869. https://doi.org/10.1016/j.biomaterials.2007.07.013

9. Duan, Y., Feng, D., Li, T., Wang, Y., Jiang, L., & Huang, Y. (2024). Comparison of lumbar interbody fusion with 3D-printed porous titanium cage versus polyetheretherketone cage in treating lumbar degenerative disease: a systematic review and meta-analysis. World Neurosurgery, 183, 144-156. https://doi.org/10.1016/j.wneu.2023.12.111

10. McGilvray, K. C., Easley, J., Seim, H. B., Regan, D., Berven, S. H., Hsu, W. K., ... & Puttlitz, C. M. (2018). Bony ingrowth potential of 3D-printed porous titanium alloy: a direct comparison of interbody cage materials in an in vivo ovine lumbar fusion model. The Spine Journal, 18(7), 1250-1260. https://doi.org/10.1016/j.spinee.2018.02.018

11. Liu, S. X., Zeng, T. H., Chen, C. M., He, L. R., Feng, A. P., Jhang, S. W., & Lin, G. X. (2024). 3D-printed porous titanium versus polyetheretherketone cages in lateral lumbar interbody fusion: a systematic review and meta-analysis of subsidence. Frontiers in medicine, 11, 1389533. https://doi.org/10.3389/fmed.2024.1389533

12. Stephan, S. R., Kanim, L. E., & Bae, H. W. (2021). Stem cells and spinal fusion. International Journal of Spine Surgery, 15(s1), 94-103. https://doi.org/10.14444/8057

13. Makarevich S., Mazurenko A., Krivorot K., Malashenko A., Potapnev M., Kosmacheva S., Danilkovich N., Ionova A. (2019) Primenenie autologichnykh mezenkhimal'nykh stvolovykh kletok s tsel'iu spondilodeza (Use of autologous mesenchymal stem cells for spinal fusion) [in Russian]. Nauka i innovatsii, (11): 79–84. https://doi.org/10.29235/1818-9857-2019-11-79-84

14. Zakrzewski, W., Dobrzyński, M., Szymonowicz, M., & Rybak, Z. (2019). Stem cells: past, present, and future. Stem cell research & therapy, 10(1), 68. https://doi.org/10.1186/s13287-019-1165-5

15. Eltorai, A. E., Susai, C. J., & Daniels, A. H. (2017). Mesenchymal stromal cells in spinal fusion: current and future applications. Journal of orthopaedics, 14(1), 1-3. https://doi.org/10.1016/j.jor.2016.10.010

16. Gomez-Ruiz, V., Blanco, J. F., Villarón, E. M., Fidalgo, H., López-Parra, M., & Sánchez-Guijo, F. (2023). Autologous mesenchymal stem cell transplantation for spinal fusion: 10 years follow-up of a phase I/II clinical trial. Stem Cell Research & Therapy, 14(1), 78. https://doi.org/10.1186/s13287-023-03298-4

17. Gentile, P., Orlandi, A., Scioli, M. G., Di Pasquali, C., Bocchini, I., & Cervelli, V. (2012). Concise review: adipose-derived stromal vascular fraction cells and platelet-rich plasma: basic and clinical implications for tissue engineering therapies in regenerative surgery. Stem cells translational medicine, 1(3), 230-236. https://doi.org/10.5966/sctm.2011-0054

18. Sharma, S., Muthu, S., Jeyaraman, M., Ranjan, R., & Jha, S. K. (2021). Translational products of adipose tissue-derived mesenchymal stem cells: Bench to bedside applications. World journal of stem cells, 13(10), 1360. https://doi.org/10.4252/wjsc.v13.i10.1360

19. Roato, I., Belisario, D. C., Compagno, M., Verderio, L., Sighinolfi, A., Mussano, F., ... & Ferracini, R. (2018). Adipose-derived stromal vascular fraction/xenohybrid bone scaffold: An alternative source for bone regeneration. Stem cells international, 2018(1), 4126379. https://doi.org/10.1155/2018/4126379

20. Pappa, E. I., Barbagianni, M. S., Georgiou, S. G., Athanasiou, L. V., Psalla, D., Vekios, D., ... & Sideri, A. I. (2023). The use of stromal vascular fraction in long bone defect healing in sheep. Animals, 13(18), 2871. https://doi.org/10.3390/ani13182871

21. Liu, J., Li, Y., Zhang, Y., Zhao, Z., & Liu, B. (2025). Engineered stromal vascular fraction for tissue regeneration. Frontiers in Pharmacology, 16, 1510508. https://doi.org/10.3389/fphar.2025.1510508

22. Pfirrmann, C. W., Metzdorf, A., Zanetti, M., Hodler, J., & Boos, N. (2001). Magnetic resonance classification of lumbar intervertebral disc degeneration. spine, 26(17), 1873-1878. https://doi.org/10.1097/00007632-200109010-00011

23. Modic, M. T., Steinberg, P. M., Ross, J. S., Masaryk, T. J., & Carter, J. R. (1988). Degenerative disk disease: assessment of changes in vertebral body marrow with MR imaging. Radiology, 166(1), 193-199. https://doi.org/10.1148/radiology.166.1.3336678

24. Schizas, C., Theumann, N., Burn, A., Tansey, R., Wardlaw, D., Smith, F. W., & Kulik, G. (2010). Qualitative grading of severity of lumbar spinal stenosis based on the morphology of the dural sac on magnetic resonance images. Spine, 35(21), 1919-1924. https://doi.org/10.1097/BRS.0b013e3181d359bd

25. Zuk PA, Zhu M, Mizuno H, Huang J, Futrell JW, Katz AJ, et al. Multilineage cells from human adipose tissue: implications for cell-based therapies. Tissue Eng. 2001; 7(2):211-228. https://doi.org/10.1089/107632701300062859

26. Sarsenova, M., Raimagambetov, Y., Issabekova, A., Karzhauov, M., Kudaibergen, G., Akhmetkarimova, Z., ... & Ogay, V. (2022). Regeneration of osteochondral defects by combined delivery of synovium-derived mesenchymal stem cells, TGF-β1 and BMP-4 in heparin-conjugated fibrin hydrogel. Polymers, 14(24), 5343. https://doi.org/10.3390/polym14245343

27. Tan, G. H., Goss, B. G., Thorpe, P. J., & Williams, R. P. (2007). CT-based classification of long spinal allograft fusion. European Spine Journal, 16(11), 1875-1881. https://doi.org/10.1007/s00586-007-0376-0

28. Liu, D., Chan, J. L., Eleanore, A., DeCost, K., Luk, J., Neukam, L. C., ... & Whitmore, R. G. (2025). Radiographic and Clinical Comparison of Polyetheretherketone Versus 3D-Printed Titanium Cages in Lumbar Interbody Fusion—A Single Institution's Experience. Journal of Clinical Medicine, 14(6), 1813. https://doi.org/10.3390/jcm14061813

29. Farré-Guasch, E., Bravenboer, N., Helder, M. N., Schulten, E. A., Ten Bruggenkate, C. M., & Klein-Nulend, J. (2018). Blood vessel formation and bone regeneration potential of the stromal vascular fraction seeded on a calcium phosphate scaffold in the human maxillary sinus floor elevation model. Materials, 11(1), 161. https://doi.org/10.3390/ma11010161

30. Yu, L., Shi, Q., Zhang, B., & Xu, J. (2022). Genetically modified mesenchymal stem cells promote spinal fusion through polarized macrophages. Laboratory Investigation, 102(3), 312-319. https://doi.org/10.1038/s41374-021-00693-4

Дегенеративті бел омыртқа ауруларын емдеудің инновациялық әдісі: Аутологиялық стромальды-тамырлық фракцияны қолданатын бел омыртқаралық спондилодез

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Түйіндеме

Зерттеудің мақсаты: дегенеративті бел омыртқа аурулары бар науқастарда, май тінінің аутологиялық стромальды-тамырлық фракциясымен толтырылған, титандық кейдж қолданылған бел омыртқааралық спондилодездің клиникалық және радиологиялық нәтижелерін бағалау.

Консервативті емге әсері жоқ дегенеративті бел омыртқа ауруы бар отыз науқас проспективті бір орталықты зерттеуге енгізілді. Барлық науқастарға артқы немесе трансфораминалды бел омыртқаралық спондилодез жасалды, ол жүйке құрылымдарын декомпрессиялауды, транспедикулярлық фиксацияны және аутологиялық сүйекпен және май тінінің стромальды-тамырлық фракциясын қамтитын жасушалық биокомпозиттік гидрогельмен толтырылған кеуекті титандық денеаралық кейдж имплантациясын қамтыды. Бел аймағындағы және төменгі аяқтардағы ауырсыну визуалды аналогтық шкала арқылы, ал еңбек және тұрмыстық белсенділіктің бұзылуы Освестри сауалнамасы бойынша операцияға дейін, операциядан кейін бір, үш–төрт және он екі айда бағаланды. Радиологиялық бағалау рентгенологиялық зерттеуді, денеаралық аймақтың компьютерлік томография денситометриясын және он екі айда сүйек бітісуін Tan классификациясы бойынша градациялауды қамтыды.

Ота кезінде неврологиялық немесе имплантатқа байланысты асқынулар тіркелген жоқ, жара жазылуы барлық науқастарда асқынусыз өтті. Он екі айлық бақылау барысында белдегі және аяқтағы ауырсыну мен функционалдық шектеулер айқын төмендеді, науқастардың көпшілігі ауыр бұзылыстар санатынан минималды бұзылыстар санатына өтті. Компьютерлік томографияда кейдж аймағындағы сүйек тығыздығының біртіндеп артуы анықталды, бұл межтеловой сүйек блогының пісіп-жетілуін көрсетті. Он екі айда науқастардың жетпіс пайызында толық спондилодез, жиырма пайызында жартылай бітісу, он пайызында бірполюсті псевдоартроз анықталды, екіполюсті псевдоартроз жағдайлары тіркелген жоқ.

Май тінінің аутологиялық стромальды-тамырлық фракциясымен біріктірілген кеуекті титандық кейдж қолданылған бел омыртқаралық спондилодез бірінші операциядан кейінгі жылы сенімді сегменттік тұрақтандыруды, сүйек бітісінүінің жоғары жиілігін және ауырсыну мен функцияның клиникалық тұрғыдан маңызды жақсаруын қамтамасыз етті.

Түйін сөздер: бел омыртқалары, омыртқааралық дискінің дегенерациясы, омыртқаның спондилодезі, титан, май тіні, стромальды-тамырлық фракция, мезенхималық бағаналы жасушалар.

Инновационный метод лечения дегенеративных заболеваний поясничного отдела позвоночника: Межтеловой спондилодез с применением аутологичной стромально-васкулярной фракции

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Резюме

Цель исследования: оценить клинические и радиологические результаты межтелового спондилодеза поясничного отдела позвоночника с использованием титанового кейджа, заполненного аутологичной стромально-васкулярной фракцией жировой ткани, у пациентов с дегенеративными заболеваниями поясничного отдела позвоночника.

В проспективное одноцентровое исследование были включены тридцать пациентов с дегенеративным заболеванием поясничного отдела позвоночника, резистентным к консервативной терапии. Всем больным выполнен задний или трансфораминальный межтеловой спондилодез поясничного отдела позвоночника с декомпрессией, транспедикулярной фиксацией и имплантацией пористого титанового межтелового кейджа, заполненного аутокостью и клеточным биокомпозитным гидрогелем, содержащим стромально-васкулярную фракцию жировой ткани. Интенсивность боли в поясничной области и нижних конечностях оценивали по визуальной аналоговой шкале, степень инвалидизации — по индексу Освестри до операции, через один, три–четыре и двенадцать месяцев после вмешательства. Радиологическая оценка включала спондилографию, компьютерную томографию с денситометрией межтеловой зоны и градацию степени спондилодеза по классификации Tan через двенадцать месяцев.

Интраоперационных неврологических и имплантат-ассоциированных осложнений не отмечено, заживление послеоперационных ран у всех пациентов протекало первичным натяжением. В течение двенадцати месяцев наблюдалось выраженное снижение интенсивности болевого синдрома в пояснице и ногах и степени инвалидизации, большинство пациентов перешли из категории выраженных нарушений в категорию минимальных. По данным компьютерной томографии отмечено последовательное повышение плотности костной ткани в зоне кейджа, что отражает формирование и созревание межтелового костного блока. Через двенадцать месяцев полный спондилодез зарегистрирован у семидесяти процентов пациентов, частичный — у двадцати процентов, признаки однополюсного псевдоартроза — у десяти процентов; случаев двуполюсного псевдоартроза не выявлено.

Межтеловой спондилодез поясничного отдела позвоночника с применением пористого титанового кейджа в сочетании с аутологичной стромально-васкулярной фракцией жировой ткани обеспечивает надежную сегментарную стабилизацию, высокую частоту формирования костного блока и клинически значимое улучшение болевого синдрома и функции в течение первого послеоперационного года.

Ключевые слова: поясничный отдел позвоночника, дегенеративное заболевание межпозвонкового диска, спондилодез позвоночника, титан, жировая ткань, стромально-васкулярная фракция, мезенхимальные стволовые клетки.

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