# RETROSPECTIVE OF THE EXPERIMENTAL MORPHOLOGICAL STUDY OF 1991 FROM THE STANDPOINT OF EVALUATING THE EFFECTIVENESS OF ANTERIOR DYNAMIC CORRECTION OF ADULT SCOLIOSIS

***S.V. Kolesov, V.S. Pereverzev***
*National Medical Research Center of Traumatology and Orthopedics n.a. N.N. Priorov, Moscow, Russia*

The article reviews the dissertation work of M.M. Usmanov, "Changes in the Intervertebral Disc with Limited Damage to its Elements and Implantation of Various Materials: an Experimental Study", defended in 1991. This study is of great interest to us in the light of the development and advancement of anterior dynamic correction of scoliosis in patients with completed and close to complete growth, where we believe the partial nucleotomy to be a key moment for ensuring optimal results. The dissertation describes an experimental morphological study on rabbits and convincingly proves that limited damage to the intervertebral disc elements can affect the strength properties of the spinal motion segment. A direct correlation between the morphological state of the intervertebral disc and the strength characteristics of the spine is shown. It was established that changes in the strength characteristics of spinal segments depend on the nature and amount of regenerating tissue in the intervertebral disc. This information can confirm and explain the effectiveness of the new approach to treating scoliosis.

**Key Words:** scoliosis correction; intervertebral disc injury; experimental study.

Please cite this paper as: *Kolesov SV, Pereverzev VS. Retrospective of the experimental morphological study of 1991 from the standpoint of evaluating the effectiveness of anterior dynamic correction of adult scoliosis. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2025;22(1):6–14. In Russian.*

*DOI: http://dx.doi.org/10.14531/ss2025.1.6-14*

Anterior release is known and widely used in the surgical treatment of idiopathic scoliosis (IS) as the first procedure, followed by traction and posterior deformity correction [1–4]. The goal of disc removal is to both enhance spinal flexibility and improve further correction of the deformity with posterior rigid fixation [4–6]. The efficacy of prior anterior release in IS regarding better deformity correction compared to the posterior approach only was not proven, and thus the indications for the combined approach are still controversial. However, in recent years, the technique of vertebral body tethering (VBT) has been proposed, which involves the use of a single flexible cord and a series of screws placed in the vertebral bodies in the transcortical manner on the convex side from the anterior approach. This approach assumes that patients with growth potential have self-correction of deformity through growth modulation with preservation of spinal mobility, yet no interventions are performed on the intervertebral discs in this case [7–10]. There are various reports that the success rate of the technique reaches only 57–59 % [11], with reports of better outcomes in patients with completed and close to complete bone growth, up to 74 % of cases [12].

Therefore, for adults, another technique – ASC (Anterior Scoliosis Correction), has been proposed [11, 13]. The core of this technique consists of the following key points:

1) the correction is performed in patients with either completed or close to complete spinal growth;

2) the correction is performed as a one-stage procedure without growth modulation;

3) an anterolateral approach is used for correction, and 2 polyethylene terephthalate cords are placed in the vertebral bodies;

4) a partial discectomy is performed at all levels of fixation to considerably increase the degree of correction, derotate the vertebrae, and reduce the number of implant-associated complications.

The majority of articles about anterior dynamic scoliosis correction are dedicated to the Vertebral Body Tethering (VBT) technique, which is used in children for growth modulation; however, it is usually connected with a certain number of implant-associated complications such as cord ruptures and hyper- or hypocorrection [9, 11, 14–16]. Nonetheless, the technology is unquestionably groundbreaking since it enables both correction of scoliosis and preservation of mobility in the operated segment, particularly when used in patients with completed and close to complete bone growth [11, 13].

Dynamic scoliosis correction in adults with IS is a very new field, the efficacy and potential of which remain to be understood. Betz and Antonacchi, the authors of the dynamic scoliosis fixation technique, in contrast to the term VBT used in growing patients, proposed

to define this technique as the Anterior Scoliosis Correction (ASC) when using it for patients with complete growth [11, 17]. Still there are practically no articles fully analysing the use of this technique in adults.

The ASC technique has been used in our country since 2019, and some of its outcomes have already been presented [13], including those that have demonstrated stability of the achieved correction, a low number of complications, and preservation of mobility in the operated segment for two to five years.

In order to understand the reason why ASC technique provides such stable outcomes, an experimental work was planned. While analysing the literature, we have found a study that, in our opinion, fully covered this issue back in 1991, more than 30 years ahead of its time.

In 1988, Stepan Timofeevich Vetrile was appointed Head of the Department of Spine Pathology at the National Medical Research Center of Traumatology and Orthopedics n.a. N.N. Priorov (CITO; Moscow). At that time, a postgraduate student Mirgiyas Mirkamilovich Usmanov was sent to him from the Uzbek Soviet Socialist Republic. He became the first postgraduate student of Professor S.T. Vetrile and was assigned the study entitled "Changes in the Intervertebral Disc with Limited Damage to its Elements and Implantation of Various Materials [18]." The thesis was successfully defended in 1991. Only two articles were published on its materials, and it did not draw attention.

In 1991, grafts were used very rarely in spine surgeries. When planning his study, S.T. Vetrile pursued an objective: he wanted to develop a puncture treatment technique for degenerative injuries of the spine (in fact, a forerunner to endoscopy). Performing intervertebral disc fenestration was to confirm that this technique increases the stability of the operated segment. Besides Professor Vetrile and the postgraduate student Usmanov, a morphologist M.N. Pavlova, and Professor N.S. Gavryushenko took part in the study. A retrospective review of this dissertation not only inspires admiration for the authors' remarkable foresight but also provides appreciation for its exceptional level: methodology, comprehensive experimental scope, morphological studies quality, and presentation.

Therefore, we considered it possible to present the analysis of this dissertation in a separate article, applying its outcomes to the technology of dynamic correction of adult scoliosis (ASC) when surgery is performed on the intervertebral discs in the fixation area.

The objective is to retrospectively analyse the experimental and morphological study of surgeries on intervertebral discs from the standpoint of evaluating the effectiveness of nucleotomy in anterior dynamic correction of scoliosis in patients with complete and close to complete bone growth.

## Materials and Methods

The main part of the study deals with intervertebral disc surgeries in chinchilla rabbits. A total of 154 mature rabbits were used in the experiment; experimental surgeries on lumbar intervertebral discs were performed on 135 of them. Animals were divided into 2 large groups considering the characteristics of the procedures:

– Group I: animals with limited damage to the soft tissue component of the disc (annulus fibrosus and nucleus pulposus), including:

0 – damage within the disruption of the annulus fibrosus area;

1 – perforation of all layers of the annulus fibrosus;

2 – perforation of the annulus fibrosus with removal of the nucleus pulposus;

– Group II: animals with limited damage to the soft tissue component and endplates of the disc including:

3 – damage to the endplate within the damaged area of the annulus fibrosus;

4 – perforation of the annulus fibrosus with removal of the nucleus pulposus and damage to the endplates;

5 – with replacement of the soft-tissue component of the disc defect with a biopolymer graft;

6 – with replacement of the soft-tissue component of the disc defect with a carbonaceous graft;

7 – with replacement of the defect of the soft tissue component and vertebral endplates with a biopolymer graft;

8 – with replacement of the defect of the soft tissue component and vertebral endplates with a carbonaceous graft.

All surgeries were performed under anaesthesia via a transperitoneal approach. There were 15 animals for each modification of the surgery; 6 of them were subjected to the study of strength properties (2 rabbits for each period of the study). The intervertebral discs of the remaining nine rabbits were studied using morphological techniques (3 for each study period).

In order to identify the trends of morphological changes in intervertebral discs and strength properties of vertebral segments, all animals were divided into 3 groups: the first group included animals studied within 14 days; the second group included animals studied within 30 days; and the third group included animals studied within 90 days after the surgery.

In order to determine grafted materials changes over time, the intervertebral discs of four rabbits were subjected to morphological examination after 1.5 years.

The control group comprised 15 animals; nine of these animals also underwent examination of vertebral segments for strength properties (3 for each period).

Therefore, a total of 182 intervertebral disc specimens (91 animals) were subjected to morphological examination, and 378 lumbar spine segments (63 animals) were subjected to strength properties testing.

The mobility test was performed on Zwick-1464, a universal testing machine, by the three-point bending technique (Fig. 1).

During the tests, a special derotation device was used (Fig. 2).

Soft tissue and transverse processes were removed from the test fragment prior to testing. Pressure was applied at a rate of 5 mm/min (Fig. 3).

Today, we are mostly focused on the surgical outcomes of procedures performed without carbon and polymer grafting.

## Results

Using statistical processing of the data obtained in the experiment, an increase in load resistance in the operated discs by 2–3 times was demonstrated. The more extensive the disc injury performed, the more resistant the disc became to stress. Even simple excision of part of the annulus fibrosus resulted in an increased load resistance of the disc. When grafts were used, these values increased even more.

It is interesting to note that when the annulus fibrosus was injured, the defect was rapidly filled first with granulation and then with scar tissue, while the hydrated part of the nucleus pulposus retained its structure (Figs. 4, 5).

Consequently, damage to the outer and structural zone of the annulus fibrosus does not adversely change the histological structure of the nucleus pulposus and adjacent vertebral bodies (Fig. 6).

More extensive disc injuries show that the nucleus pulposus is replaced by mature fibrous tissue with a predominance of fibrous elements. The boundary between the nucleus pulposus and the annulus fibrosus is not visible. Partial injury of all zones of the annulus fibrosus with extirpation of the nucleus pulposus results in replacement of the defect with dense scar tissue. The integrity of the annulus fibrosus is recovered (Fig. 7).

When the endplates are injured along with the disc, osseocartilaginous enlargements are formed, resulting in an increased volume of the epiphyses of the vertebral bodies adjacent to the disc. A dumbbell shape develops: the intervertebral disc becomes smaller because of sclerosis of the hydrated disc tissue and fibrosis of the central part of the disc, creating a hypomobile block between adjacent vertebral bodies.

Therefore, damage to an intervertebral disc affects the mechanical properties of a given level segment.

The following findings were made in the course of the study:

1) disruption of the structural arrangement of the nucleus pulposus and reduction of intra-disc pressure during puncture injury of the annulus fibrosus result in gradual formation of fibrous tissue and fibrosis of the nucleus pulposus;

2) when soft tissue components of the intervertebral disc are injured, accompanied by additional disruption of the integrity of bone and cartilage tissue of adjacent vertebrae, tissue regeneration occurs with the formation of fibrous osseocartilaginous fusion of adjacent vertebral bodies;

3) the connective tissue and osseocartilaginous regenerate that develops during the process of intervertebral disc recovery determines the strength properties of the damaged disc and the corresponding spinal segment; the strength properties of the tissue regenerate of the intervertebral disc are increasing in relation to the volume of tissue injury;

4) the implanted carbon and polymer grafts in the tissues of the intervertebral disc induce a weak inflammatory response from the adjacent tissues, which promotes regeneration of the injured disc elements; fibrocellular tissue and fibrous capsule are developing around the grafts;

5) the use of grafts for partial replacement of the intervertebral disc tissue defect enhances the strength properties of the damaged intervertebral segments;

6) microsurgeries resulting in limited damage to separated elements of the intervertebral disc provide a mean of 2–3 times greater fusion strength of adjacent vertebral bodies compared to intact segments due to regenerating tissues and thereby contribute to the stabilisation of damaged spinal segments.

## Discussion

The ASC technique involves a minimally invasive intermuscular thoracotomy approach for thoracic, thoracolumbar, or lumbar curves and, unlike VBT, involves the concept of de-tethering through anterior release, since surgeries on the anterior longitudinal ligaments, annular capsule, and discs are performed. It is possible to restore normal kyphosis and even preserve segmental vessels in addition to deformity correction by segmental cord tension on the convex side and derotation during surgery for ASC [11]. Unlike VBT, the indications for ASC are broader, including skeletally mature patients with deformities greater than 70° with less physiological mobility of the primary curve; therefore, the surgery is slightly more aggressive. Meanwhile, the issue of spinal mobility in the fixation zone after disc release and the risk of developing autofusion remain controversial. However, there are isolated reports of satisfactory functional outcome and quality of life in a 50-year-old female patient 7 years after ASC [17]. There are no more long-term data published for adult patients, which is probably associated with the novelty of the technique. Moreover, ASC demonstrates at least equal outcomes in patients with a formed skeleton compared to those with VBT. At least, the data show a more stable outcome and a low number of mechanical complications in adults, which is probably a consequence of disc surgery [12, 13, 19] and, according to M.M. Usmanov's dissertation, enhances an increased strength property of the injured spinal motion segments.

To summarize the presented study and extrapolate its outcomes to dynamic spine correction technology, we can conclude that partial discectomy in ASC technique is the key to a stable long-term outcome. When the nucleotomy is used in different volumes, the load on the cord, which is always the weak link in dynamic correction, can be minimized. In accordance with the analyzed experimental study, the formation of connective tissue in the disc injury area increases the stability of the segment with preservation of its slight mobility.

The more damaged the disc is, the greater its delayed stability; the less damage, the greater its mobility.

A study of vertebral segment movements on cadaveric specimens has shown that both limited and radical nucleotomy alter disc mechanics. These

changes include decreased pressure, decreased height, increased disc deformation and flexibility, and increased bulging of the annulus fibrosus [20–24]. Limited nucleotomy of a healthy disc is marked by swelling and remodeling of the remaining tissue, which can recover mechanical functionality [20–25]. In contrast, radical nucleotomy eliminates tissue redistribution, thereby leaving a cavity in the centre of the disc. It has been demonstrated that limited nucleotomy did not change the axial stiffness of the segment during compression [20]. Subsequent cyclic loading and unloading allow the disc to restore the mechanical condition to intact values due to swelling and redistribution of the remaining nucleus pulposus tissue. Previous studies have suggested that the increased disc deformation under load is associated with the amount of nucleus material removed [20, 21], while others have shown that a reduction in pressure without a large amount of nucleus pulposus removed has minimal effect on disc bulging.

Therefore, understanding the functional role of intervertebral disc injury is crucial for developing and evaluating strategies for its application in ASC, which currently provides a pathway for further research.

Implementing a sufficiently long dynamic correction and using titanium screws and elastic cord on the convex side of the curvature, we can increase the stability of the correction by partial discectomy at all levels: fibrous tissue and scarring combined with elastic fixation with polyethylene terephthalate cord provide the necessary stability. This is the key point of the assessed study. The use of carbon and polymeric materials placed in the disc as indicated can both supplement correction and enhance spinal fixation. However, this is more related to explaining the effectiveness of different options for anterior mechanical support than to dynamic spinal correction.

Therefore, the accumulation and analysis of clinical material using ASC technique is essential. Nevertheless, the results of the study performed more than 30 years ago at the CITO Department of Spine Pathology do not only reflect biological phenomena of disc changes under different variants of their targeted injury but also provide an explanation of the effectiveness of ASC technique, contributing both to the experimental and clinical justification of its wider implementation.

While analyzing the study of different volumes of discectomy in experiments as applied to the dynamic correction of scoliosis, an important conclusion can be made that determines the technology of correction and its preservation in the long term. Firstly, at this stage of correction, the discectomy provides greater coaptation of the vertebral bodies in the area of the corrective maneuver. This enhances the derotating effect of the surgery. Secondly, the achieved correction is preserved in the lack of bone block.

According to the experimental data, even excision of the annulus fibrosus alone results in the formation of scar tissue in this area, which increases the load resistance of the segment by 2-3 times. The formation of fibrous tissue in the discectomy area increases the strength of the segment and reduces the load on the elastic cord used to maintain correction and mobility in the fixation area. Therefore, by performing different volumes of

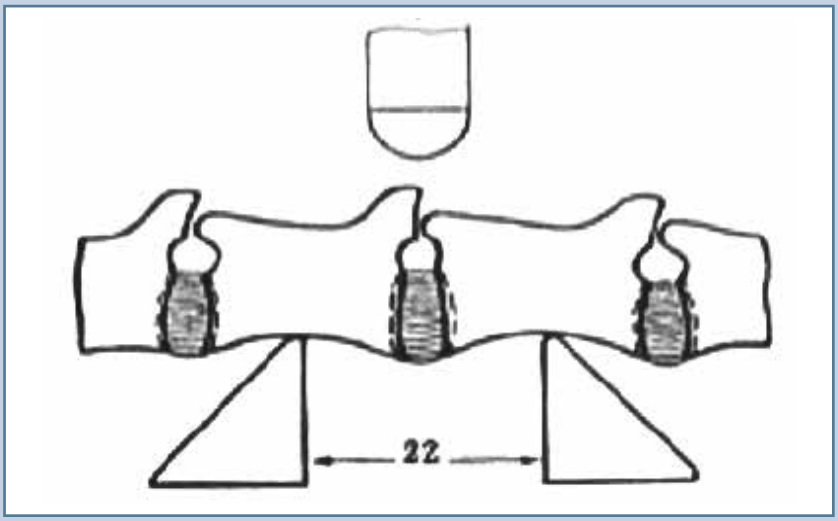


**Fig. 1**
Scheme of testing a spinal segment using the three-point bending technique [23]

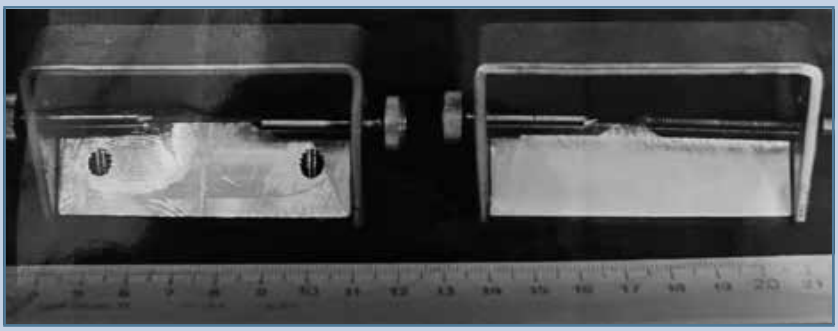

**Fig. 2**
Derotating device for testing the strength of a spinal segment using the three-point bending technique [23]

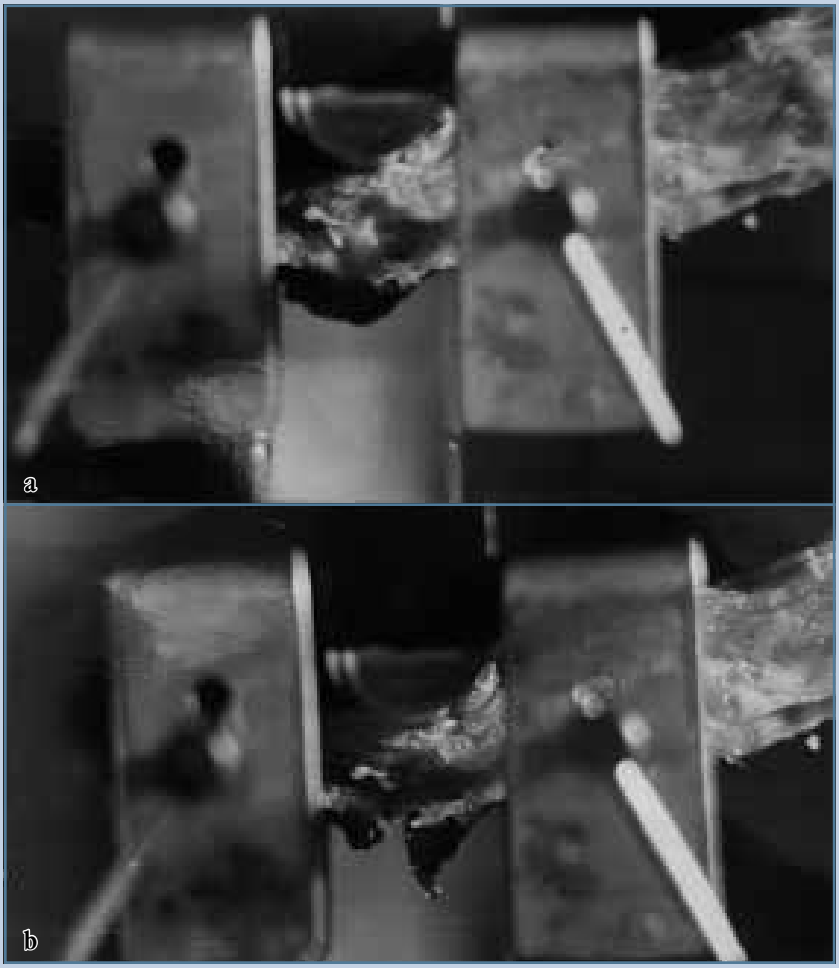


**Fig. 3**
Picture of a spinal segment before **(a)** and after **(b)** the test

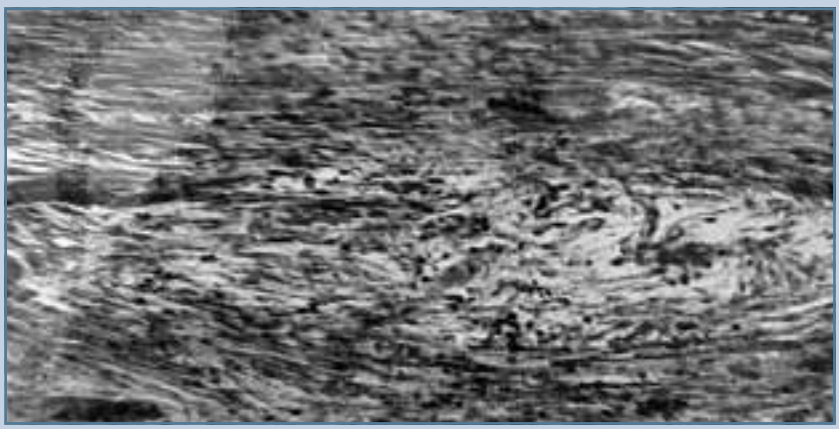

**Fig. 4**
Micrograph: mature granulation tissue filling a defect in the outer area of the annulus fibrosus (hematoxylin-eosin)

discectomy, we can impact elasticity and mobility in the area of fixation. Meanwhile, the fibrous tissue supports the segment and allows the cord to perform in more favourable conditions, preventing it from rupturing.

## Conclusion

According to the results of an experimental and morphological study in rabbits, it has been persuasively demonstrated that limited damage to the intervertebral disc elements can affect the strength properties of the spinal motion segment. A direct correlation between the morphological condition of the disc and the strength properties of the spine has been shown. It was determined that changes in the strength properties of spinal motion segments depend on the type and amount of regenerating tissue in the intervertebral disc. This information may confirm and explain the success of nucleotomy in anterior dynamic correction of scoliosis, thereby ensuring stable long-term outcomes.

*The study had no sponsors. The authors declare that they have no conflict of interest.*
*The study was approved by the local ethics committee of the institution.*
*All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.*

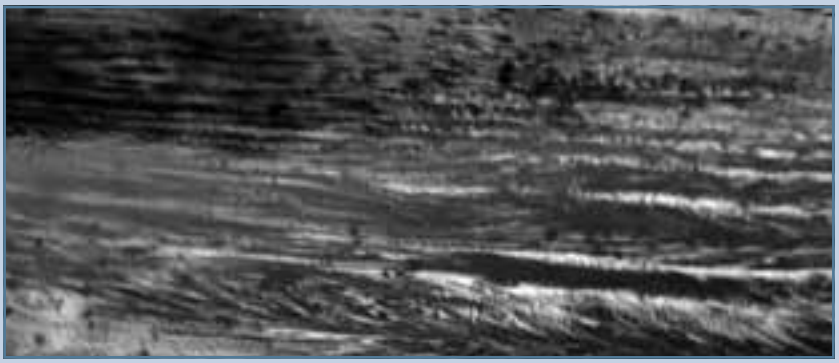

**Fig. 5**
Histogram: the defect of the annulus fibrosus is replaced by dense scar tissue, the nucleus pulposus retains hydrated tissue, the internal area of the annulus fibrosus retains vascular structure; period 1 month (hematoxylin-eosin)

**Fig. 6**
Micrograph: the inner area of the annulus fibrosus retains the cartilaginous layered structure; period 14 days.

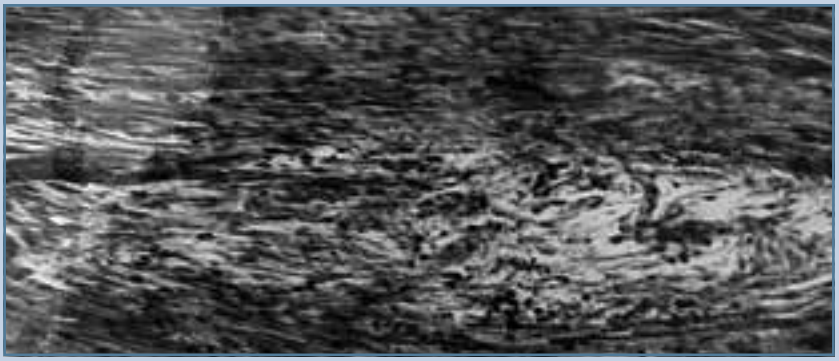

**Fig. 7**
Mature granulation tissue filling the defect of the outer area of the annulus fibrosus (hematoxylin-eosin)

## References

1. **Arlet V, Jiang L, Ouellet J.** Is there a need for anterior release for 70–90 degrees masculine thoracic curves in adolescent scoliosis? Eur Spine J. 2004;13:740–745. DOI: 10.1007/s00586-004-0729-x
2. **Luhmann SJ, Lenke LG, Kim YJ, Bridwell KH, Schootman M.** Thoracic adolescent idiopathic scoliosis curves between 70 degrees and 100 degrees: is anterior release necessary? Spine. 2005;30:2061–2067. DOI: 10.1097/01.brs.0000179299.78791.96
3. **Lonner BS, Haber L, Toombs C, Parent S, Shah SA, Lenke L, Sucato D, Clements D, Newton PO.** Is anterior release obsolete or does it play a role in contemporary adolescent idiopathic scoliosis surgery? A matched pair analysis. J Pediatr Orthop. 2020;40:e161–e165. DOI: 10.1097/BPO.0000000000001433
4. **Shi Z, Chen J, Wang C, Li M, Li Q, Zhang Y, Li C, Qiao Y, Kaijin G, Xiangyang C, Ran B.** Comparison of thoracoscopic anterior release combined with posterior spinal fusion versus posterior-only approach with an all-pedicle screw construct in the treatment of rigid thoracic adolescent idiopathic scoliosis. J Spinal Disord Tech. 2015;28:E454–E459. DOI: 10.1097/BSD.0b013e3182a2658a
5. **Ruf M, Letko L, Matis N, Merk HR, Harms J.** Effect of anterior mobilization and shortening in the correction of rigid idiopathic thoracic scoliosis. Spine. 2013;38:E1662-E1668. DOI: 10.1097/BRS.0000000000000030
6. **Newton PO, Wenger DR, Mubarak SJ, Meyer RS.** Anterior release and fusion in pediatric spinal deformity. A comparison of early outcome and cost of thoracoscopic and open thoracotomy approaches. Spine. 1997;22:1398–1406. DOI: 10.1097/00007632-199706150-00020
7. **Baroncini A, Rodriguez L, Verma K, Trobisch PD.** Feasibility of single-staged bilateral anterior scoliosis correction in growing patients. Global Spine J. 2021;11:76–80. DOI: 10.1177/2192568219892904
8. **Miyanji F, Pawelek J, Nasto LA, Rushton P, Simmonds A, Parent S.** Safety and efficacy of anterior vertebral body tethering in the treatment of idiopathic scoliosis. Bone Joint J. 2020;102-B:1703–1708. DOI: 10.1302/0301-620X.102B12.BJJ-2020-0426.R1
9. **Baroncini A, Trobisch PD, Migliorini F.** Learning curve for vertebral body tethering: analysis on 90 consecutive patients. Spine Deform. 2021;6:141–147. DOI: 10.1007/s43390-020-00191-5
10. **Newton PO, Kluck DG, Saito W, Yaszay B, Bartley CE, Bastrom TP.** Anterior spinal growth tethering for skeletally immature patients with scoliosis: A retrospective look two to four years postoperatively. J Bone Joint Surg Am. 2018;100:1691–1697. DOI: 10.2106/JBJS.18.00287
11. **Antonacci C, Antonacci MD, Bassett WP, Cuddihy LA, Haas AR, Cerrone JL, Haoson DS, Bets RR.** Treatment of mature/maturing patients with adolescent idiopathic scoliosis (Sanders ⩾ 5) using a unique anterior scoliosis correction technique. Med Res Arch. 2022;9(12). DOI: 10.18103/mra.v9i12.2632
12. **Hoernschemeyer DG, Boeyer ME, Robertson ME, Loftis CM, Worley JR, Tweedy NM, Gupta SU, Duren DL, Holzhauser CM, Ramachandran VM.** Anterior vertebral body tethering for adolescent scoliosis with growth remaining: a retrospective review of 2 to 5-year postoperative results. J Bone Joint Surg Am. 2020;102:1169–1176. DOI: 10.2106/JBJS.19.00980
13. **Kolesov SV, Pereverzev VS, Kazmin AI, Morozova NS, Shvec VV, Raspopov MS, Bagirov SB.** Can anterior dynamic correction be considered a new standard of surgical treatment of idiopathic scoliosis in patients with completed and terminating growth? Retrospective single-center analysis of long-term results. N.N. Priorov Journal of Traumatology and Orthopedics. 2024;31(2):147–157. DOI: 10.17816/vto617680
14. **Zhang H, Fan Y, Ni S, Pi G.** The preliminary outcomes of vertebral body tethering in treating adolescent idiopathic scoliosis: a systematic review. Spine Deform. 2022;10:1233–1243. DOI: 10.1007/s43390-022-00546-0
15. **Baroncini A, Trobisch PD, Birkenmaier C, Da Paz S, Migliorini F.** Radiographic results after vertebral body tethering. Z Orthop Unfall. 2022;160:387–392. DOI: 10.1055/a-1387-8334
16. **Ergene G.** Early-term postoperative thoracic outcomes of videothoracoscopic vertebral body tethering surgery. Turk Gogus Kalp Damar Cerrahisi Derg. 2019;27:526–531. DOI: 10.5606/tgkdc.dergisi.2019.17889
17. **Antonacci M, Yung A, Antonacci C, Cuddihy L, Betz R.** Treatment for an adult patient with slowly progressive idiopathic scoliosis using a unique anterior scoliosis correction technique: a case report. Med Res Arch. 2022;10(12). DOI: 10.18103/mra.v10i12.3345
18. **Usmanov MM.** Changes in the intervertebral disc with limited damage to its elements and implantation of various materials (experimental study): MD/PhD Thesis. Moscow, 1991. 164 p..
19. **Kolesov SV, Pereverzev VS, Panteleyev AA, Shvets VV, Gorbatyuk DS.** The first experience of anterior dynamic correction of scoliosis in adolescents with complete growth and adults: surgical technique and immediate results. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2021;18(3):19-29. DOI: 10.14531/ss2021.3.19-29
20. **Brinckmann P, Grootenboer H.** Change of disc height, radial disc bulge, and intradiscal pressure from discectomy. An in vitro investigation on human lumbar discs. Spine. 1991;16:641–646. DOI: 10.1097/00007632-199106000-00008
21. **Goel VK, Nishiyama K, Weinstein JN, Liu YK.** Mechanical properties of lumbar spinal motion segments as affected by partial disc removal. Spine. 1986;11:1008–1012. DOI: 10.1097/00007632-198612000-00007
22. **Ishihara H, Tsuji H, Hirano N, Ohshirna H, Terahata N.** Biorheological responses of the intact and nucleotomized intervertebral discs to compressive, tensile, and vibratory stresses. Clin Biomech (Bristol, Avon). 1993;8:250–254. DOI: 10.1016/0268-0033(93)90034-F
23. **Seroussi RE, Krag MH, Muller DL, Pope MH.** Internal deformations of intact and denucleated human lumbar discs subjected to compression, flexion, and extension loads. J Orthop Res. 1989;7:122–131. DOI: 10.1002/jor.1100070117
24. **Shea M, Takeuchi TY, Wittenberg RH, White AA 3rd, Hayes WC.** A comparison of the effects of automated percutaneous diskectomy and conventional diskectomy on intradiscal pressure, disk geometry, and stiffness. J Spinal Disord. 1994;7:317–325.
25. **Vresilovic EJ, Johannessen W, Elliott DM.** Disc mechanics with trans-endplate partial nucleotomy are not fully restored following cyclic compressive loading and unloaded recovery. J Biomech Eng. 2006;128:823–829. DOI: 10.1115/1.2354210

**Address correspondence to:**
Pereverzev Vladimir Sergeyevich
National Medical Research Center of Traumatology and Orthopedics n.a. N.N. Priorov,
10 Priorova str, Moscow, 127299, Russia,
vcpereverz@gmail.com

*Received 29.01.2025*
*Review completed 03.03.2025*
*Passed for printing 10.03.2025*

*Sergey Vasilyevich Kolesov, DMSc, traumatologist-orthopedist, Head of the Spine Pathology Department, National Medical Research Center of Traumatology and Orthopedics n.a. N.N. Priorov, 10 Priorova str, Moscow, 127299, Russia, ORCID: 0000-0002-4252-1854, dr-kolesov@yandex.ru.*
*Vladimir Sergeyevich Pereverzev, MD, PhD, surgeon, Spine Pathology Department, National Medical Research Center of Traumatology and Orthopedics n.a. N.N. Priorov, 10 Priorova str, Moscow, 127299, Russia, ORCID: 0000-0002-6895-8288, vcpereverz@gmail.com.*