DOI 10.18019/1028-4427-2017-23-2-154-161

Vertebral fractures over the metal structure in patients with osteoporosis. Can we prevent these injuries?

I.V. Basankin[1,2], K.K. Takhmazyan[1], A.A. Afaunov[1,2], O.N. Ponkina[1], S.B. Malakhov[1], V.K. Shapovalov[1], A.L. Volynskiy[1]

[1]Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia
[2]Kuban State Medical University, Krasnodar, Russia

Thematic justification Compression stress fractures of the vertebrae at the upper border with a metal structure are a serious problem, especially in extensive stabilization and in patients with osteoporosis. Nowadays, there is a lack of information on prevention of the fracture of the vertebrae adjacent to the metal structure. **Purpose** Compare experimentally the efficiency of cemented vertebroplasty and laminar band fixation of the cranial vertebra adjacent to the TPF level for prevention of fractures in osteoporosis. **Study design** Biomechanical cadaver study. **Materials and methods** We used the cadaver material obtained from females in the age from 66 to 81 years. The extension of the blocks withdrawn was from Th10 to L4 (7 vertebrae). L1 fracture was simulated in all the blocks by its mechanical destruction. A total of 15 blocks were studied divided into 3 groups of five units each: group 1 – controls (cemented TPF of Th12-L2); group 2 – cemented TPF of Th12-L2 + Th11laminar fixation with the «Universal Clamp»; group 3 – cemented TPF of Th12-L2 and preventive vertebroplasty of Th11 and L3. We used the axial load with a universal servo-hydraulic testing machine «Walter + bay ag» LFV-10-T50 (Switzerland). Compression was carried out until graphic signs of fracture were displayed. We took X-rays of blocks before and after the study. **Results** The control group revealed the appearance of vertebral fractures just above the metal structure (Th11). The first graphic signs of fracture were detected in the range of 0.78-0.94 kN (mean 0.86 ± 0.13784). The group with laminar fixation using the «Universal Clamp» revealed fractures of Th10 and Th11. The first graphic oscillations corresponding to a fracture were detected in the range of 1.12–1.48 kN (mean 1.21 ± 0.385227). The group with preventive vertebroplasty of Th11 and L3 revealed fractured vertebrae adjacent to the vertebroplasty (Th10). In this case, the first graphic oscillations corresponding to a fracture were detected in the range of 1.78-2.05 kN (mean 1.898 ± 0.222441). **Conclusion** The overlying vertebra is at increased risk of fracture when transpedicular fixation is used. The use of laminar fixation with the «Universal Clamp» does not prevent vertebral fracture over the pedicle system (Th11) but provides an increase of resistance to the vertebral fracture by 1.5 times. Preventive vertebroplasty of overlying vertebra is an effective way to prevent a pathological fracture (Th11), and also increases the resistance of the overlying (Th10) vertebra to fracture by 2–2.5 times.
Keywords: experiment, spine, fracture, metal instrumentation, transpedicular fixation, vertebroplasty

INTRODUCTION

The number of patients with lesions in the thoracic and lumbar spine due to osteoporosis has been constantly growing [1]. The main method of treatment for this pathology in cases of considerable vertebral body compression and deformity is transpedicular fixation (TPF) with cemented screw implantation that is stronger than the standard one which is cementless [2, 3]. This method prevents destabilization of the implanted screws and of fixed vertebral motor segments (VMS). However, an active use of two or more segments for fixation by surgical treatment of spine fractures in osteoporosis showed that such management resulted in an increased load on the adjacent VMS and led to fractures of the vertebrae adjacent to the fixed ones [4]. Moreover, it is known that the same problem in the vertebra adjacent to TPF exists even in cases of absent osteoporosis [5]. The experimental and clinical studies in patients that had extensive TPF demonstrated the vulnerability of the vertebrae that lie cranial to TPF system to stress fractures [6–8]. The search for an optimal prevention of such complications is a current problem in contemporary vertebrology.

Purpose of our study was to compare the efficiency of cemented vertebroplasty and laminar band fixation of the cranial vertebra adjacent to the TPF level for prophylaxis of PJF in osteoporosis.

Basankin I.V., Takhmazyan K.K., Afaunov A.A., Ponkina O.N., Malakhov S.B., Shapovalov V.K., Volynskiy A.L. Vertebral fractures over the metal structure in patients with osteoporosis. Can we prevent these injuries? *Genij Ortopedii*. 2017. T. 23. No 2. pp. 154-161. DOI 10.18019/1028-4427-2017-23-2-154-161

MATERIAL AND METHODS

For conduction of the experiment, we used the cadaver material harvested from 15 females in the age from 66 to 81 years who died from somatic diseases. The blocks that extended from Th10 to L4 (7 vertebrae) were harvested. The mandatory condition was preservation of the integrity of vertebrae, discs and capsulo-ligamentous apparatus. Paravertebral muscles were dissected and removed completely.

All the blocks were treated after harvesting and studied. Radiographs were taken in two mutually perpendicular projections. Computed tomography and densitometry were also used. CT and CT-densitometry were performed with the use 129-sections CT system CT SOMATOM SENSATION 24 OPEN. Criteria for inclusion into the study were absence of expressed frontal or sagittal deformities, absence of destructive changes in the spine, absence of ankylosing spondyloarthritis manifestations, and presence of radiographic and densitometric signs of osteoporosis (T-criterion lower than –2.5).

Unstable L1 fracture of type A (1996 AO/ASIF classification) with destruction up to 45 – 60 % of the vertebral body mass in its cranial part was simulated in all the blocks harvestered. It was achieved by resection of the upper anterior part of L1 body along with the Th12–L1 intervertebral disc. Thus, the conditions were created that approximated to a live situation in which a kyphotic deformity appears by the loss of ventral vertebral parts supportability. The choice of L1 was not incidental as far as the statistics shows that this vertebra is commonly affected [9].

Upon the L1 injury, a 4-screw transpedicular system with cemented screw reinforcement was implanted through Th12–L2 in all the blocks. The amount of the bone cement implanted for screw strengthening was 7–8 ml per each vertebra. Accuracy of screw position was controlled by C-arm image intensifier *Siemens Arcadis* and with a stationary radiographic system *Philips Duo Diagnost* upon completion of fixation. Thereby, two vertebrae above and lower the TPF system remained intact in each anatomical block prepared.

Then, all the anatomical blocks were blindly divided into three groups, each having five samples.

Group 1 was controls who had a simulated L1 fractures, cemented TPF with a 4-screw system in Th12–L2. Two vertebrae above and lower the fixed VMS were intact.

Group 2 had similar cemented TPF of Th12–L2 but bilateral laminar fixation with the “Universal Clamp” of Th11pedicle was used.

Group 3 was cemented TPF in Th12–L2 and additional vertebroplasty of Th11 and L3 bodies. Vertebroplasty was performed with the standard transpedicular method with an introduction of 7 to 8 ml of bone cement into each vertebra through two needles (13G) from both sides. The cement volume introduced was 25 % from the volume of the vertebral body [10]. Its filling the vertebra was controlled radiographically.

The anatomical blocks of the vertebral segments thus prepared of the main and control groups were tested with a vertical mechanical impact for detection of their strength. Stress tests were conducted in a test laboratory of the Priorov Central Institute of Traumatology and Orthopaedics (CITO, Moscow) using a universal servo-hydraulic testing machine «Walter+bay ag» LFV-10-T50 (Switzerland). Vertebral segments blocks were fixed in special platforms between the transversal beams of the test machine. The proximal unit of the platform that fixed the cranial vertebra of the preparation tested was attached to a strain-meter that was rigidly connected with a mobile transverse beam of the test machine. The distal unit of the platform that fixed the caudal vertebra was placed in a three-jaw gripper that was fixed on the axis of the motor that was rigidly attached to a stationary beam. The distance between the beams was preliminary set according to the vertical sizes of the preparations tested (**Fig. 1**). A zero point on the meter was set before the test. The machine was launched into compression mode. An increasing vertical test load with the rate of beam approximation of 5mm/sec was initiated. Compression was executed with the effort force from 0 to 3–5 kN.

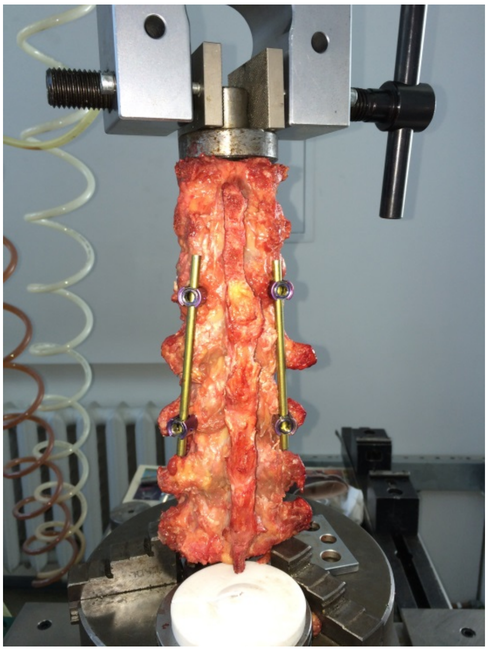

Fig. 1 Anatomic block of vertebral segments prior to a load test

Under an increasing load, an inconsiderable kyphotic deformity cranial to the TPF level was first noted. Further on, a staged destruction of the tested blocks occurred that was accompanied by a characteristic sound and increasing deformity that continued without an increase of loading. The data obtained were processed on a calculation unit of the testing machine. The parameters of the changes in the deformity in the preparations tested in dependence on the load applied was recorded as diagrams with the coordinates of "vertical load" (N) and "compression deformity" (mm).

During the tests, a vertical force acting on the anatomical blocks of vertebral segments was defined that caused primary local destruction (fractures) that were reflected on the diagrams as "oscillations" of the graphic line that showed the compression deformity dependence on the load applied. Those parameters characterize the general strength of the anatomic blocks of vertebral segments tested. Angular deformities of the tested vertebral segments that were the result of the vertically directed load were recorded with a digital photo- and video shooting. The diagrams obtained were transformed into tables that showed the deformity dependence of the tested preparations on the load applied for subsequent analysis. Load discretion in the tables was 20N. Quantitative characteristics of the results of the experiments were statistically processed defining a standard error of the mean values.

Upon completion of the loading tests, all the blocks were studied in radiographs and CT for visualization of fractures. The condition of the TPF system was also checked for instability signs. Local destruction zones were identified (fractures) in the bone mass of the vertebrae with implanted screws as well as in the cranial and caudal vertebrae from VMS fixed with transpedicular systems. The findings of imaging studies were compared with graphical diagrams that reflected fractures.

RESULTS

Radiography and CT of the blocks of the vertebral segments did not reveal any instability signs of transpedicular screws implanted into the vertebral bodies of Th12 and L2 with the use of bone cement in all the 15 anatomical preparations of all the groups. Moreover, there were no cases of fractures of the vertebrae into which the screws with bone cement were implanted. Also, there was not any case of broken transpedicular system component (screw, rod) or disassembly of its elements.

In group 1 (controls without prevention of the levels adjacent to the fixed VMS), the first graphic oscillations that corresponded to the appearance of a fracture were revealed in the range of 0.78–0.94 kN (mean, 0.86 ± 0.13784) (**Fig. 2**). Further increase of load with the test machine resulted in a rough destruction of anatomic preparations and appearance of kyphotic deformity that was observed visually. Graphic signs of severe compression of vertebrae were noted within the range of 1.24–1.6 kN (mean, 1.426 ± 0.292438).

Radiographic study of the anatomic preparations after the experiment revealed a fracture of the vertebra above the transpedicular system (Th11) in all blocks of the control group. All the rest vertebrae remained intact. There were no radiographic signs of fracture in them. **Figure 3** shows the radiographs before and after the tests in the control group anatomic preparations without the use of vertebral fracture prevention close to the transpedicular system.

In group 2 that had a bilateral laminar fixation with the "Universal clamp" through the pedicle of the above lying vertebra (Th11) over the transpedicular system, the findings in the similar conditions of loading tests differed from the control group. The first graphic oscillations that corresponded to a fracture were revealed in the range of 0.96-1.48 kN (mean, 1.21 ± 0.385227). The signs of a rougher destruction were seen in the range of 2.06-2.61 kN (mean, 2.44 ± 0.69685).

Figure 4 shows a diagram that reflects the occurrence of fracture in the anatomic preparation of this group in dependence on the vertical loading applied.

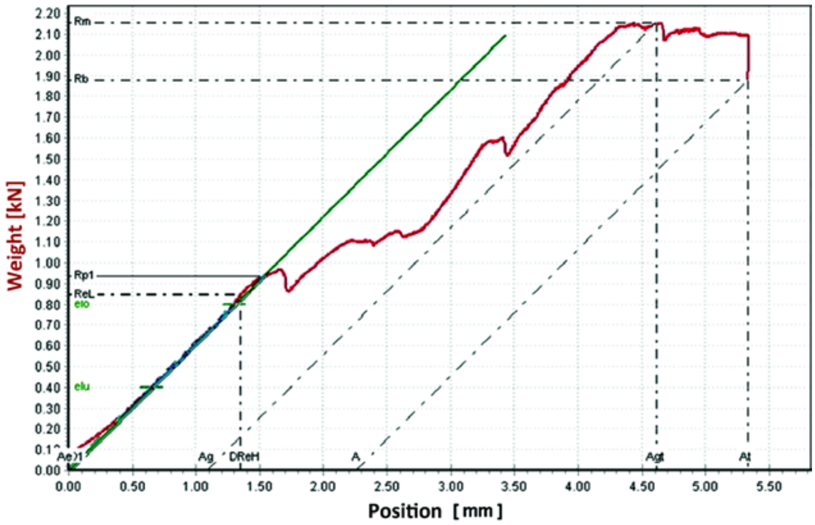

Fig. 2 Diagram of deformity dependence upon the vertical load applied to the vertebral segments tested in control group

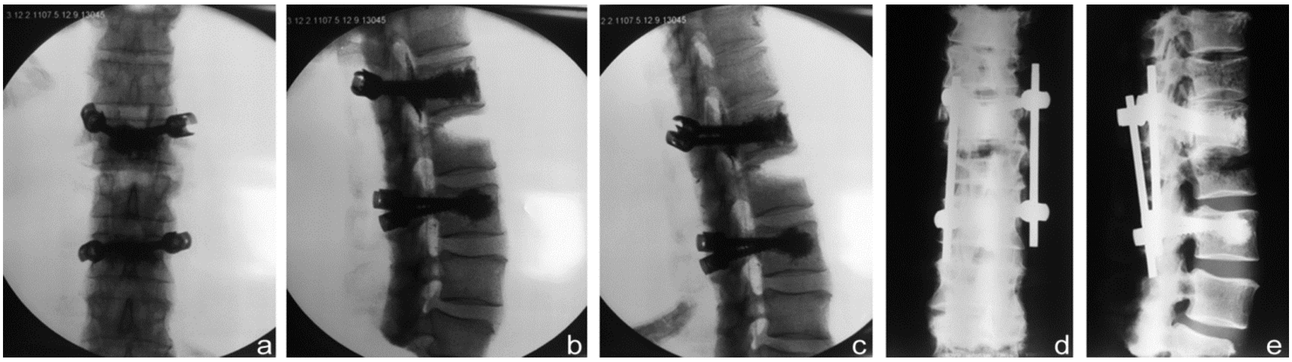

Fig. 3 Radiographs of control group vertebral segments blocks prior to loading tests (**a, b**); cemented implantation of screws into Th12 and L2; L1 cranial body part resected with the above lying disc; radiographs of the same block after the loading tests (**c, d**). Th11 body fracture was diagnosed and seen as a loss of its vertical size and fracture lines in the lateral view (**e**) as well as reduction of the vertical vertebral body size on the left side in the AP view (**d**)

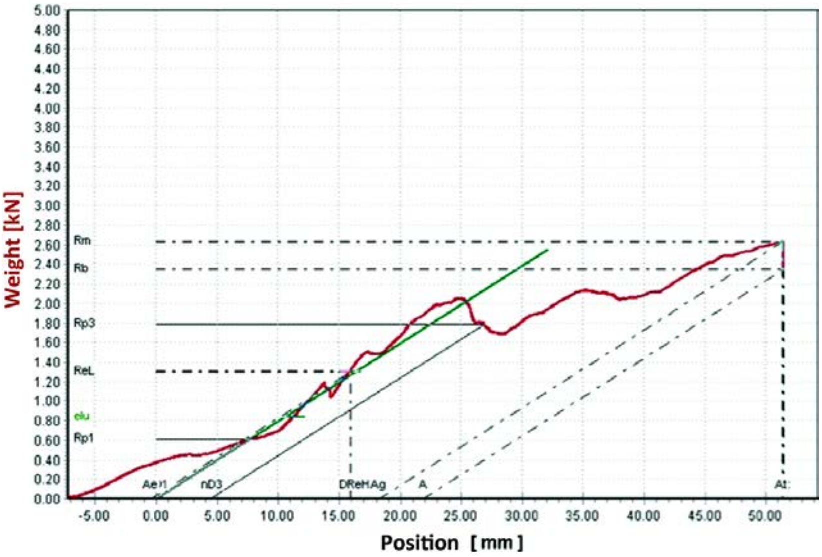

Fig. 4 Diagram of deformity dependence upon the vertical load applied to the vertebral segments tested in group 2 with laminar fixation

The analysis of the diagram shows that a gradual increase in loading up to 1.20 kN did not result in any oscillations. The first graphic oscillation appeared once the load of 1.20 kN was achieved and corresponded to a microfracture in the vertebral body (range, 1.20–1.01 kN). One more inconsiderable oscillation was noted once the load continued to grow within the range of 1.51–1.42 kN. A more serious graphic fall was revealed at the level of 2.06 kN. A sharp fall of resistance (2.06–1.70 kN) means a deeper destruction of vertebral trabeculae. A similar situation was observed in each block of this group.

Radiographic study and post-experimental CT detected fractures in the vertebrae above the metal structures (Th10 and Th11). Th10 body fracture was diagnosed in two cases and fracture in Th11 body in one more case. Fractures in both these vertebrae at a time were revealed in two more cases. Most destruction was observed in the vertebrae closest to the metal structure (Th11).

Figure 5 shows radiographs and CT findings before and after the experiment of the anatomical preparation from the group with a preventive laminar fixation of the pedicle of the above lying vertebra Th11.

In group 3 with the anatomic vertebral segments blocks and vertebropalsty of Th11 and L3 bodies, the findings differed significantly from the previous groups in the conditions of similar loading tests. The first graphic oscillation appeared and corresponded to the fracture in the range of 1.78–2.05 kN (mean, 1.898 ± 0.222441). Signs of rough vertebral destruction were revealed in the range of 2.12–2.78 kN (mean, 2.522 ± 0.528848).

Figure 6 shows the diagram of deformity dependence upon the vertical load applied to the vertebral segments blocks of the main group and reflects the occurrence of Th10 fracture (over the vertebra with vertebroplasty).

The analysis of the diagram shows that a gradual increase in loading up to 2.05 kN did not result in any oscillations. The first graphic oscillation appeared once the load of 2.05 kN was achieved and corresponded to the first microfracture in the vertebral body (range, 2.05–2.02 kN). Soon after, with an inconsiderable increase in loading a more serious graphic fall was revealed at the level of 2.14–1.94 kN. Further increase in loading showed a deeper destruction of vertebral trabeculae.

The subsequent radiographic study showed that the vertebrae Th11 and L3 that were adjacent to the transpedicular system and underwent vertebroplasty were resistant to the mechanical loading tested. Their fractures were not revealed in none of the cases. However, fractures of the proximal Th10 vertebra that lay over Th11 were diagnosed in all five blocks of the main group.

Figure 7 shows radiographs of the main group anatomic preparation with vertebroplasty of vertebral bodies adjacent to the TPF level before and after the experiment.

The findings obtained in the experiment that characterize loads that provoke vertebral fractures in the adjacent VMS vertebrae in all the groups are given in **Table 1**. Injured vertebra is indicated.

Indices of general strength of the vertebral segment blocks in the main and the other groups studied in regard to the vertical mechanical impact that characterize the loads required for local fracture to occur are presented graphically in **Figure 8**.

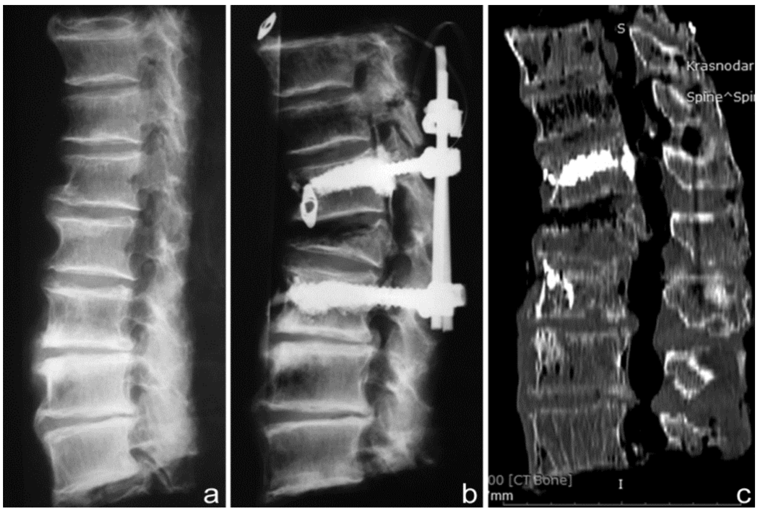

Fig 5 Radiographs of the vertebral segments blocks of group 2 with preventive laminar Th11 fixation: radiograph of the initial anatomic preparation (**a**); radiograph of the same preparation after the experiment (**b**); sagittal CT reconstruction after the experiment (**c**). Th11 fracture over the metal structure was detected. There is reduction in Th11 height and vacuum phenomenon in its body. Small-size air areas in the Th10 body point to mircrofractures in Th10 body

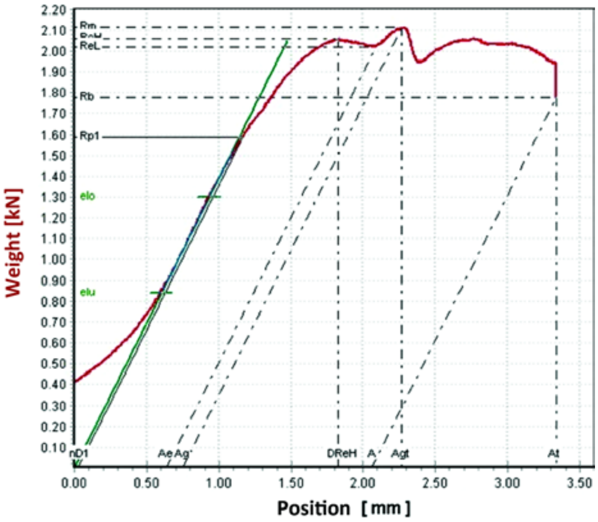

Fig 6 Diagram of deformity dependence upon the vertical load applied to the vertebral segments tested in group 3 with preventive vertebroplasty

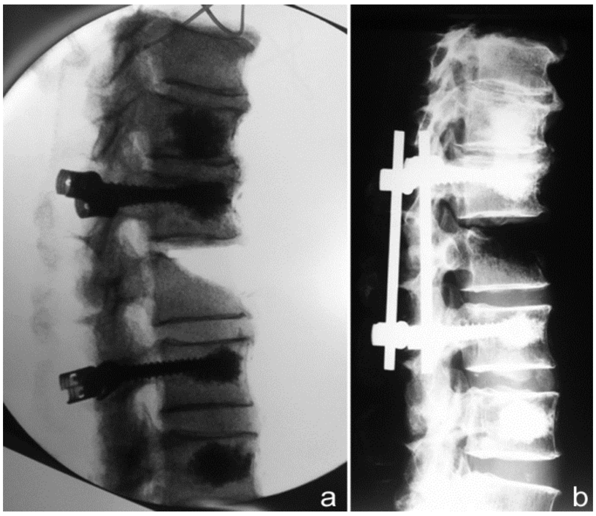

Fig. 7 Radiographs of the main group vertebral segments (vertebroplasty of Th11 and L3, adjacent to VMS): radiograph of the anatomic preparation with Th11 and L3 vertebroplasty before loading test (**a**); radiograph of the same preparation with Th11 and L3 vertebroplasty after the experiment (**b**). Th11 (with vertebroplasty) was resistant to loading impact. Fracture was revealed in the cranial Th10 vertebra over the vertebroplasty

Table 1

Characteristics of anatomic preparations of the study according to the groups and indices of the force applied at which vertebral fracture occurs

Group	Study material	Sex, age (years)	T-criterion	Force of first fracture signs	Rough destruction	Injured vertebra
Group 1 (without preventive vertebroplasty)	Block 1	F, 66	2.47	0.87	1.52	Th11
	Block 2	F, 71	2.87	0.94	1.6	Th11
	Block 3	F, 75	3.48	0.91	1.45	Th11
	Block 4	F, 68	2.49	0.8	1.32	Th11
	Block 5	F, 80	3.40	0.78	1.24	Th11
	Mean		0.86 ± 0.13784 кN		1.426 ± 0.292438кN	
Group 2 (laminar fixation with Universal Clamp)	Block 1	F, 66	3.42	1.12	2.61	Th10
	Block 2	F, 71	3.89	1.21	2.06	Th10
	Block 3	F, 65	2.39	1.28	2.95	Th10, 11
	Block 4	F, 75	3.62	0.96	2.23	Th10, 11
	Block 5	F, 69	3.51	1.48	2.35	Th10
	Средняя		1.21 ± 0.385227		2.44 ± 0.69685	
Group 3 (preventive vertebroplasty)	Block 1	F,78	2.51	1.78	2.12	Th10
	Block 2	F, 81	2.39	1.91	2.46	Th10
	Block 3	F, 79	3.89	1.8	2.51	Th10
	Block 4	F, 67	3.36	2.05	2.78	Th10
	Block 5	F, 63	2.67	1.95	2.74	Th10
	Mean		1.898 ± 0.222441		2.522 ± 0.528848	

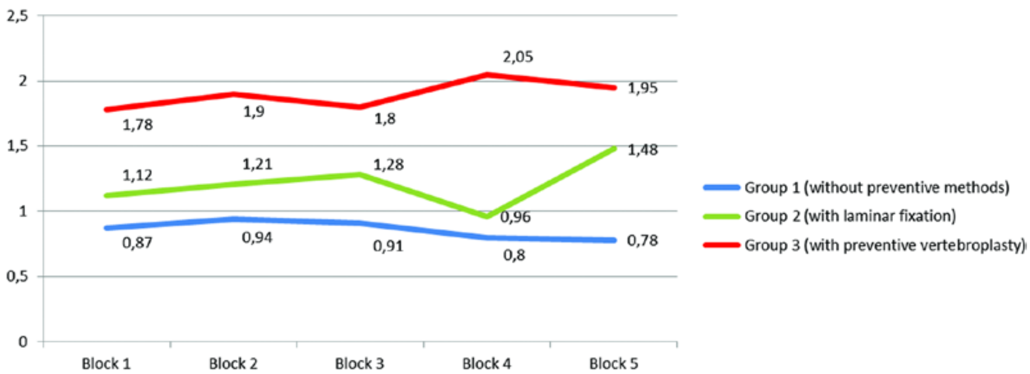

Fig. 8 General strength of the anatomic vertebral segments blocks studied in the main and control groups in regard to vertical mechanical impact

DISCUSSION

The analysis of the findings obtained by our study allows us to conclude that a gradual increase of loading that is directed vertically on the anatomic vertical segments blocks first results in an inconsiderable kyphotic deformity in the control group predominantly due to Th11–Th12 disc compression. Thereby, the ventral parts of Th11 appear in a biomechanical compromise in regard to further vertical force augmentation. As a result, even a relatively small amount equal to 0.78–0.94 kN causes local destruction in the ventral part of the Th11 body bone mass. Further growth of the force promotes a rougher destruction of the body trabeculae in this vertebra that in the diagram is reflected as several “drops” that characterize the ongoing fracture processes that progress and cause an expressed kyphotic deformity. Therefore, the experiments with the vertebral segments blocks of the control group showed that the ventral parts of TH11 body that is closest to the transpedicular system is the most weak point in regard to the vertical load.

In case laminar fixators are used through the pedicles of the above lying vertebra, a border zone is formed at this level between the spinal part fixed by the rigid metal instrumentation and a free mobile overlying zone of the unfixed spine. The buffer zone thus formed at the level of laminar fixation, on the one hand, makes the protective level semi-rigid and decreases the direct loading on the above lying vertebra over the metal structure. Both these factors result in a more considerable stability of the vertebra adjacent to the transpedicular system. As a results, the first graphic signs of fracture in this groups were revealed at the values between 0.96 and 1.48 that was 1.2 to 1.6 times higher than the similar parameters in the control group. Therefore, the use of laminar band fixation may be considered as a preventive measure of a vertebral fracture over the transpedicular system.

In the experimental group 3 with a preventive vertebroplasty, fractures did not occur at similar loads in the Th11 bodies where bone cement had been introduced. The blocks sustained the efforts up to 1.78–2.05 kN that exceeds by 1.7–2.3 times the similar parameters in the control froup. Thereby, fractures occurred in the uncemented bodies of Th10, that is over the vertebrae with vertebroplasty (Th11). Thus, vertebroplasty of the vertebra Th11 that lies over the TPF level is an effective method of its fracture prevention and may be considered as prophylaxis to a stress fracture and proximal kyphosis over the fixed VMS.

Fractures of the vertebra that lies lower were revealed in none of the anatomic preparations studied, irrespective of the presence or absence of vertebroplasty (**Fig. 9**).

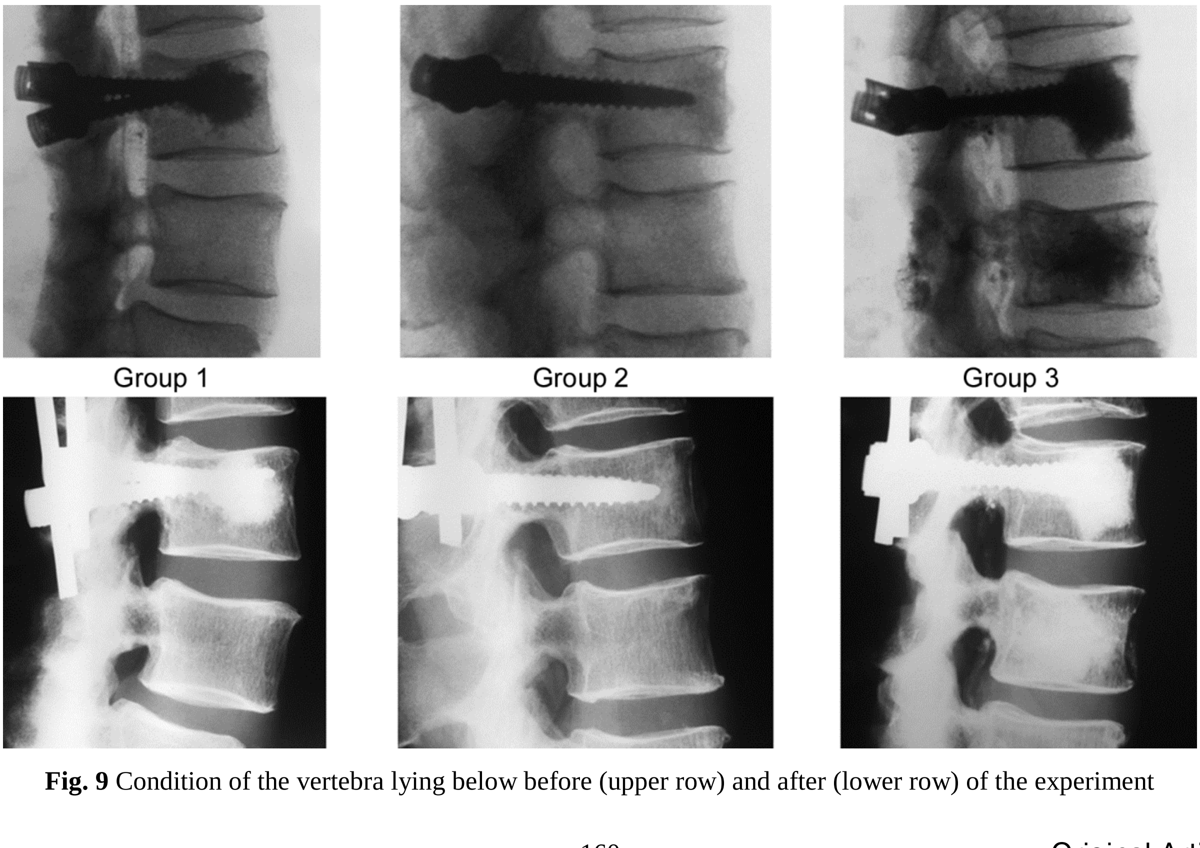

Fig. 9 Condition of the vertebra lying below before (upper row) and after (lower row) of the experiment

CONCLUSIONS

1 The most vulnerable site for a fracture to occur over the transpedicular system is the nearest vertebra located cranially.

2 Band laminar fixation through the pedicle over the metal instrumentation does not prevent a fracture but rises the resistance to its occurrence by 1.2–1.6 times.

3. Vertebroplasty of the vertebra overlying the TPF level is an effective way of its fracture prevention and may serve as a preventive measure to avoid a stress fracture and proximal kyphosis over the fixed VMS. Moreover, the resistance of the vertebra to a fracture over the vertebra with a preventive vertebroplasty can increase by 1.7–2.3 times.

4. Preventive vertebroplasty of the vertebra caudal to the fixation level is not suitable as the risk of its fracture is inconsiderable.

REFERENCES

1. Yang Z., Griffith J.F., Leung P.C., Lee R. Effect of osteoporosis on morphology and mobility of the lumbar spine. *Spine*, 2009, vol. 34, no. 3, pp. E115-E21. doi: 10.1097/BRS.0b013e3181895aca.
2. Afaunov A.A., Basankin I.V., Takhmazian K.K. Analiz rezul'tatov primeneniia transpedikuliarnoi fiksatsii s tsementnoi implantatsiei vintov pri lechenii povrezhdenii grudnogo i poiasnichnogo otdelov pozvonochnika na fone osteoporoza [Analysis of the results of using transpedicular fixation with cemented screw implantation for treatment of injuries of the thoracic and lumbar spine through osteoporosis]. *Perspektivy razvitiia vertebrologii: innovatsionnye tekhnologii v lechenii povrezhdenii i zabolevanii pozvonochnika i spinnogo mozga: materialy IV s'ezda mezhregion. obshchestvennoi organizatsii «Assotsiatsiia khirurgov-vertebrologov» s mezhdunar. uchastiem* [Prospects of vertebrology development: innovation technologies in treatment of injuries and diseases of the spine and spinal cord: Materials of IV Congress of interregional public organization “Association of surgeons-vertebrologists” with international participation]. Novosibirsk, 2013, pp. 10-16. (In Russian)
3. Burval D.J., McLain R.F., Milks R., Inceoglu S. Primary pedicle screw augmentation in osteoporotic lumbar vertebrae: biomechanical analysis of pedicle fixation strength. *Spine*, 2007, vol. 32, no. 10, pp. 1077-1083.
4. Fernández-Baíllo N., Sánchez Márquez J.M., Sánchez Pérez-Grueso F.J., García Fernández A. Proximal junctional vertebral fracture-subluxation after adult spine deformity surgery. Does vertebral augmentation avoid this complication? A case report. *Scoliosis*, 2012, vol. 7, no. 1, pp. 16. doi: 10.1186/1748-7161-7-16.
5. Lau D., Clark A.J., Scheer J.K., Daubs M.D., Coe J.D., Paonessa K.J., LaGrone M.O., Kasten M.D., Amaral R.A., Trobisch P.D., Lee J.H., Fabris-Monterumici D., Anand N., Cree A.K., Hart R.A., Hey L.A., Ames C.P.; SRS Adult Spinal Deformity Committee. Proximal junctional kyphosis and failure after spinal deformity surgery: a systematic review of the literature as a background to classification development. *Spine*, 2014, vol. 39, no. 25, pp. 2093-2102. doi: 10.1097/BRS.0000000000000627.
6. Basankin I.V., Takhmazian K.K., Afaunov A.A., Ptashnikov D.A., Ponkina O.N., Gavriushenko N.S., Malakhov S.B., Shapovalov V.K. Sposob profilaktiki perelomov smezhnykh pozvonkov pri transpedikuliarnoi fiksatsii na fone osteoporoza [A technique to prevent adjacent vertebrae fractures for transpedicular fixation through osteoporosis]. Khirurgiia Pozvonochnika, 2016, vol. 13, no. 3, pp. 8-14. (In Russian)
7. Hassanzadeh H., Jain A., El Dafrawy M.H., Ain M.C., Mesfin A., Skolasky R.L., Kebaish K.M. Three-column osteotomies in the treatment of spinal deformity in adult patients 60 years old and older: outcome and complications. *Spine*, 2013, vol. 38, no. 9, pp. 726-731. doi: 10.1097/BRS.0b013e31827c2415.
8. Martin C.T., Skolasky R.L., Mohamed A.S., Kebaish K.M. Preliminary Results of the Effect of Prophylactic Vertebroplasty on the Incidence of Proximal Junctional Complications After Posterior Spinal Fusion to the Low Thoracic Spine. *Spine Deform.*, 2013, vol. 1, no. 2, pp. 132-138. doi: 10.1016/j.jspd.2013.01.005.
9. Lehman R.A. Jr., Paik H., Eckel T.T., Helgeson M.D., Cooper P.B., Bellabarba C. Low lumbar burst fractures: a unique fracture mechanism sustained in our current overseas conflicts. *Spine J.*, 2012, vol. 12, no. 9, pp. 784-790. doi: 10.1016/j.spinee.2011.09.005.
10. Manukovskii V.A. *Vertebroplastika v lechenii patologii pozvonochnika.* Avtoref. dis. dokt. med. nauk [Vertebroplasty in treatment of the spine pathology. Extended abstract of Dr. med. sci. diss.]. SPb., 2009. 37 p. (In Russian)

Received: 30.12.2016

Information about the authors

1. Igor' V. Basankin, M.D., Ph.D., Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia, Head of Neurosurgical Department No 3; Email: basankinspine@gmail.com, basankin71@rambler.ru
2. Karapet K. Takhmazian, M.D., Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia, Neurosurgical Department No 3
3. Asker A. Afaunov, M.D., Ph.D., Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia, Head of the Department of Traumatology, Orthopaedics and Military Surgery of Kuban State Medical University; Email: afaunovkr@mail.ru
4. Ol'ga N. Ponkina, M.D., Ph.D., Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia, Head of Pathoanatomy Department; Email: ponkina_olga@mail.ru
5. Sergei B. Malakhov, M.D., Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia, Neurosurgical Department No 3
6. Vladimir K. Shapovalov, M.D., Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia, Neurosurgical Department No 3
7. Aleksei L. Volynskii, M.D., Ochapovsky Research Institute and Regional Hospital #1, Krasnodar, Russia, Neurosurgical Department No 3