EARLY ORTHOTICS IN COMPLEX TREATMENT OF CHILDREN WITH VERTEBRAL COMPRESSION FRACTURES OF THE THORACIC AND LUMBAR SPINE

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Objective. To compare the results of treatment of compression fractures of the thoracic and lumbar vertebrae in children by classical functional extension and by early orthotics with hyperextension braces.

Material and Methods. The study included 175 children aged 3 to 18 years with vertebral compression fractures of the thoracic and lumbar spine. In the study group (32 patients), early orthotics with a rigid hyperextension brace was used, in the control group (143 patients) — a standard Gorinevskaya — Dreving's technique followed by wearing a semi-rigid brace.

Results. In the study group, the average vertebral compression ratio was 63 %, WI — 0.6—0.8, and vertebral body height restoration was observed in 90.5 % of cases. In the control group, the average compression ratio was 75 %, WI — 0.75—0.9, and abnormal wedging of vertebral bodies after the treatment was observed in 48.0 % of patients. In the study group, the length of hospital stay was reduced, the mode of physical activity in the early stages was increased with better and faster restoration of vertebral bodies in comparison with the control group.

Conclusion. Application of hyperextension braces shortens hospital stay, contributes to the complete restoration of the height and shape of the damaged vertebral body, and allows for more early returning the children to the familiar social environment.

Key Words: compression fracture of the vertebra, conservative treatment, orthosis, children.

Please cite this paper as: *Vissarionov SV, Baindurashvili AG, Pavlov IV, Kokushin DN, Lein GA, Gusev MG. Early orthotics in complex treatment of children with vertebral compression fractures of the thoracic and lumbar spine. Hir. Pozvonoc. 2016;13(4):11–20. In Russian. DOI: http://dx.doi.org/10.14531/ss2016.4.11-20.*

Treatment of pediatric patients with compression fractures of the thoracic and lumbar vertebrae has remained topical over the past years [20]. This problem is very important because of the increasing number of patients with injuries of the vertebral column related to the increased number of traffic- and work-related accidents and falls from a height [4, 14, 15, 18]. Statistical data show that spine injuries account for 0.5–8.0 % of all injuries to the locomotor apparatus, and vertebral compression fractures in children account for up to 10 % of all the injuries to the vertebral column [8, 11, 21].

The conventional functional therapy is currently used to treat patients with vertebral compression fractures, which involves long-term bed rest (up to 21 days) followed by continued conservative rehabilitation in a specialized center [6]. This approach assumes that orthotics for the spine are performed only after completion of long-term period of conservative treatment [1, 14, 16]. Today, the range of orthoses used to manage compression fractures is appreciably broad. Metal and leather braces, rib-stiffened textile braces, and modular orthotic devices are typically used to unload the injured spine section [3, 10, 16, 17, 19, 21]. There are sporadic reports in the literature on early use of braces (within several days after injury) [5, 9]. However, there is no description of the exact time frame for starting brace treatment, indications for using orthoses of specific design or treatment modalities.

It should be mentioned that the procedures for designing hyperextension braces in different orthotics schools are controversial and are largely based on the immediate experience of clinicians rather than evidence.

Hence, the problem of using orthotic devices in combined conservative treatment of patients with vertebral compression fractures remains topical and requires further elaboration.

The objective of this study was to perform a comparative analysis of the outcomes of treating pediatric patients with compression fractures of thoracic and lumbar vertebrae by conventional functional extension and using early orthotics with hyperextension braces.

Material and Methods

We monitored 175 children aged 3–18 years with compression fractures (types A1.1 and A2.1 according to the Magerl's classification) of the thoracic and lumbar vertebrae. Inclusion and exclusion

criteria were elaborated to select patients to be enrolled in the study.

The inclusion criteria were as follows:

1) age of 3–18 years;

2) compression fractures of the thoracic and lumbar vertebrae;

3) isolated and multiple compression fractures of the thoracic and lumbar vertebrae;

4) time of collecting the data;

5) clinical and X-ray examination;

6) patients in the control group had undergone a complete course of conservative therapy including in-hospital treatment in a rehabilitation center;

7) patients in the study group had undergone a course of conservative therapy using early orthotic intervention with hyperextension braces;

8) the follow up was performed for at least 2 years after the end of treatment.

The exclusion criteria were as follows:

1) age under 3 years and over 18 years;

2) compression fractures of the cervical spine;

3) unstable injuries to the thoracic and lumbar spine.

All patients were divided into two groups: the control and study ones. The control group consisted of 143 patients: 26 (19 %) patients with compression fractures of a single vertebral body and 117 (81 %) patients with multiple fractures of the thoracic and lumbar vertebrae, who were receiving conservative treatment. Therapy in children with compression fractures was performed according to the conventional Gorinevskaya – Dreving's technique. Combined therapy included hospital stay during 3 weeks; patients were then transferred to a rehabilitation center to continue therapy for another 3–4 weeks. The study group consisted of 32 patients aged 3–18 years who received conservative treatment using early orthotics with a rigid hyperextension brace. In this group, 6 (18 %) patients had compression fracture of a single vertebral body of; 26 (82 %) patients, multiple compression fractures of the thoracic and lumbar vertebrae. The level of spine injury, the type and severity of vertebral body fracture, and the variants of orthoses used were investigated in this study.

The sex and age distribution of the followed-up patients is shown in Table 1.

Male gender prevailed among the control group patients (60 %), while the percentage of females in the control group was only 44 %. The prevailing age group consisted of children aged 7–12 (49 %); the percentage of patients aged 12–18 years was 47 %.

The sex and age distribution of the followed-up patients was identical in the study and control groups.

The distribution of patients in the study and control groups with respect to injury localization is shown in Figs. 1, 2.

Hence, both groups were mainly composed of children with compression fractures of the thoracic spine.

Analysis of comparison of patients in the study and control groups with respect to their sex, age, and injury localization (Table 2) demonstrated that the initial intergroup differences are not statistically significant.

An analysis of the patients with respect to the level and number of injured vertebrae revealed that 82 % of patients had compression fractures of at least two vertebrae (Table 3).

All patients in the control group received conventional in-hospital conservative therapy for vertebral compression fractures during 3 weeks: strict bed rest on a bed with the head end elevated at an angle of 30°, functional traction by means of Glisson's loop in patients with a fracture of vertebrae at the T1–T4 level or traction using armpit support and patient's own body weight when the fracture was localized below the T4 level, a course of rehabilitation therapy using the first-stage procedure developed by Gorinevskaya and Dreving, physiotherapy, and back massage. After this therapy the patient was transferred in the lying position from the hospital to the rehabilitation center; the rehabilitation therapy was continued for another 1–1.5 months (second-stage physical therapy according to the procedure developed by Gorinevskaya and Dreving). The patient was placed in a knee–elbow position on day 31 after the vertebral fracture occurrence. The recommendations after discharge from the rehabilitation center included the follow-up by a traumatologist at the community-based hospital and continuous walking for no longer than 2–3 hours while wearing a semi-rigid brace with a declinator. After 3–4 months, the patient was allowed to sit for a certain period of time; the duration of sitting bouts was daily increased by 5 min.

The study group patients received in-hospital conservative treatment aimed at eliminating pain and unloading the anterior column of the injured vertebral body. The patients were subjected to hyperextension and strictly adhered to bed rest (the procedure is identical to that described above). The treatment involved first-stage physical therapy according to the procedure developed by Gorinevskaya and Dreving during 10–15 days. A hyperextension brace was manufactured and put on the patient on day 10 after the injury. After the patient received the orthosis, he/she was adapting to wearing it. After discharge from the hospital, the patient continued to receive rehabilitation treatment that included physical therapy aimed at strengthening of the core muscles, back massage, and physiotherapeutic procedures.

Clinical examination after spine injury and the performed conservative treatment provided the data that allowed us to ascertain the presence and severity of the pain syndrome using the VAS scale, a 10 cm ruler with the images of happy and unhappy faces for children older than 3 years [23]. One side of the ruler was divided into 10 sections, 1 cm each, while the back side (intended for a patient) showed facial expression of emotions corresponding to either absence or presence of pain of different intensity. All the injured patients were examined by a neurologist upon admission. Neurological disorders were observed in none of the patients in both groups.

X-ray examination of the injured spine section in two standard views (frontal and lateral) was the basic method for diagnosing spine fractures. The X-ray images recorded before treatment were used to evaluate the type of injury to the vertebral body, the degree of kyphosis of the thoracic spine and the

Table 1
Sex and age distribution of patients in the study and control groups according to the N.P. Gundobin's classification [7], n

Age, year	Sex	
	Male	Female
Study group		
1–3	–	–
3–7	8	2
7–12	42	29
12–18	36	26
Control group		
1–3	–	–
3–7	–	1
7–12	12	4
12–18	6	9

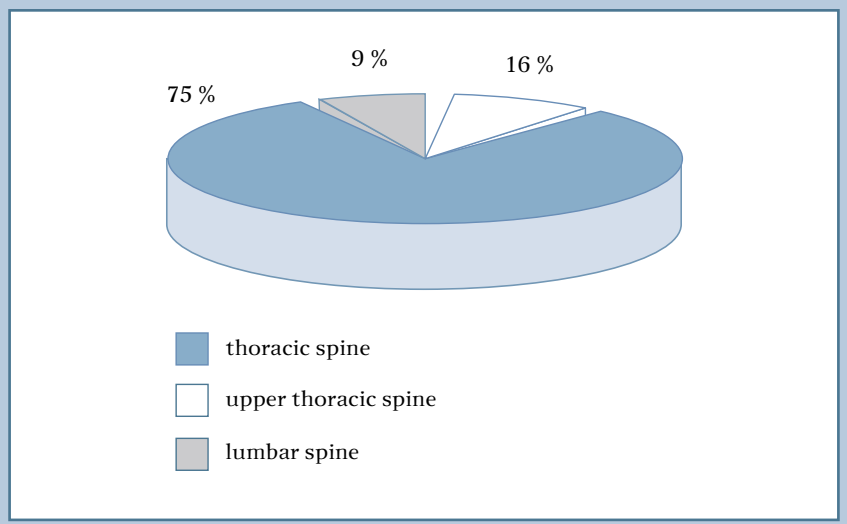

Fig. 1
Localization of injured vertebrae in patients of the study group

degree of compression of the injured vertebral body. The degree of kyphosis correction and the rate of vertebral body height restoration were determined during and after the course of conservative treatment using the X-ray images. All patients in the control and study groups underwent MRI to confirm the compression fracture and evaluate the type of vertebral injury.

The X-ray images were evaluated as follows: photos of the radiographs viewed in an X-ray viewing box were made using a digital camera and then squared-off using AutoCAD 2010 software according to the procedure proposed by Vinz [22]. The wedge index (WI) was determined.

The wedge-shaped deformity of the vertebral body and its degree of compression were evaluated both on the frontal and the anteroposterior view images. The degree of compression in isolated injury of the body of a single vertebra was determined using the procedure proposed by Vinz [22], who has singled out four degrees of compression of a vertebral body: up to 90 % of the initial height of the anterior vertebral column – minor; up to 80 % – obvious; up to 70 % – significant; and less than 70 % – severe. The ratio between the height of the ventral portion of a compressed vertebra and the half-sum of heights of the ventral sections of the superjacent and subjacent vertebrae were calculated as % (Fig. 3).

The procedure for determining the WI for each vertebral body was used in patients with multiple injuries to the adjacent vertebral bodies: WI was calculated as the ratio between the heights of the anterior and the posterior contours of the vertebral body (Fig. 4).

The WI fluctuated between 0.65 and 0.95 in compressed vertebrae; being up to 0.85 for mild degree of compression; between 0.84 and 0.70 for moderate degree of compression; and less than 0.69 for severe degree of compression [2]. The physiological WI of vertebral bodies in 6–8-year-old children is most pronounced at the T4–T9 level and varies from 0.91 to 0.95. In 9–12-year-old children, the physiological WI of the same vertebrae fluctuates within 0.92–0.94. In the age group of 13–15-year-olds, it is the lowest (0.96–0.99).

Results and Discussion

Upon admission to hospital, 71 % of patients in the study group complained of moderate pain (score 4–6); 16% of patients, mild (score 0–3) or no pain; 13%, severe pain (score 7–10). Right before orthotic intervention, induced pain (pain accompanying movements) became less intense and decreased by 3–4 VAS points. After using an orthosis for 2 weeks, pain was completely eliminated (VAS score 0). Hence, the pain syndrome was completely eliminated within two weeks and did not relapse upon regular static and dynamic load during the dynamic follow-up. This was caused by stability of the functional spinal unit at the injury level and the uniform physiological load distribution along the entire spine when using the hyperextension brace (Table 4).

An analysis of the archives of medical records revealed that all the patients in the control group complained of back pain after the injury, but pain severity was not evaluated using the VAS scale. The patients in this group did not com-

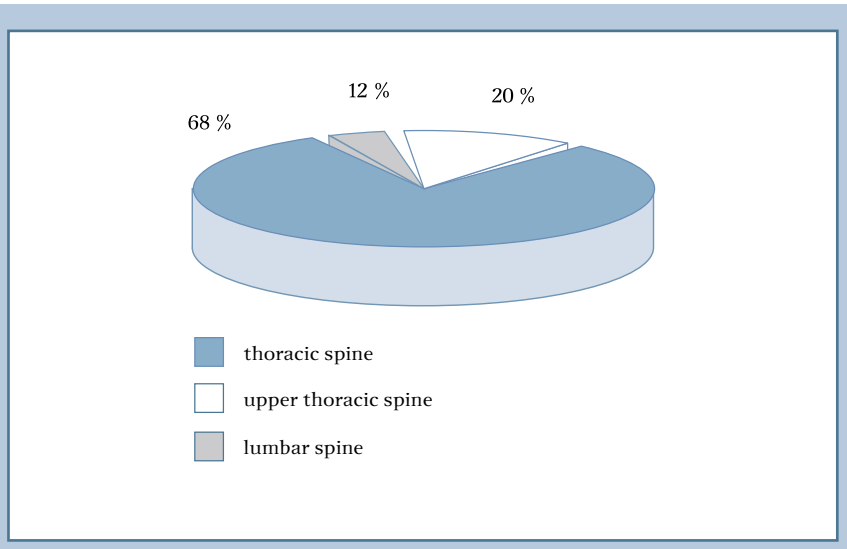

Fig. 2
Localization of injured vertebrae in the control group

Table 2

Distribution of patients in the study and control groups with respect to injury localization.

Localization	Patients, n		Significance level of the difference, P
	Study group	Control group	
T1–T4	5	28	0.8*
T5–T12	24	97	0.5*
L1–L5	3	18	0.8*

*Fischer's exact test.

Table 3

Distribution of patients with respect to the level and number of compression fractures of the vertebral bodies, n (%)

Fractured vertebrae	Fracture localization		
	T1–T4	T5–T12	L1–L5
1	7 (4)	16 (9)	9 (5)
2	10 (6)	33 (19)	16 (9)
3 and more	9 (5)	68 (39)	7 (4)

plain of back pain until the spinal injury. The control group patients completed the questionnaires on the pain syndrome 2 years after the injury (Table 5). In 34 (24 %) patients, the pain syndrome persisted and manifested itself under loading despite the treatment.

MRI examination of all the patients of the study and control groups showed a wedge-shaped deformity of the vertebral body by more than 10 % in combination with a hyperintense T2-weighted SE and T2 SPAIR (fat suppression) MR signals, which morphologically corresponded to a trabecular edema and hemorrhage in the spongy substance.

Wearing fabric braces with metallic arch bars and a retractor was prescribed to patients in the control group during the treatment, one month after injury. The braces of this type ensure rigid and elastic fixation of the spine at the level of the lower thoracic, lumbar, and sacral spine sections in the functionally favorable position. The following brace models were manufactured for the patients in the study group: for five patients with injury to the anterior portions of the vertebral bodies at the T2–T4 levels, the hyperextension braces for the thoracic spine with semi-rigid head support made of 10 mm thick Pedilen rigid foam (Fig. 5); for two patients, hyperlordosing braces (Fig. 6). The overwhelming majority of patients (20) wore the models of hyperextension braces for the thoracic spine after the injury to the anterior portions of the vertebral bodies at the T5–T12 level (Fig. 7). Five patients had compression fractures of the vertebrae in different spine sections; they wore the combined brace models for the thoracic and lumbar spine (Fig. 8).

The hyperextension brace for the upper thoracic spine [12] is used in patients with injured anterior portions of vertebral bodies at the T2–T4 level. In terms of its design, this model is a hyperextension brace for the thoracic spine combined with a semi-rigid head support made of 10 mm thick Pedilen rigid foam fixed to the brace using an arch bar system consisting of the central axial bar attached to the brace shell in the projection of the spinal axis and a horseshoe-shaped plate attached to the head support through leather loops. This type of brace is used in patients with compression fractures of vertebral bodies at the T5–T12 level.

The hyperlordosing brace for the lumbar spine is used in patients with compression fractures of vertebral bodies at the L1–L5 level. In terms of its design, this brace consists of a polyethylene shell cut along its lateral surface. Paravertebral compression pads are placed at the level of the injured vertebrae, engaging the superjacent and subjacent vertebrae, provided that no more than two vertebrae are injured. For the more extensive injuries (over two vertebrae), the pads are positioned only at the level of the fracture area. The pressure is applied to the paravertebral regions. On the ventral side, the pads are also positioned with allow-

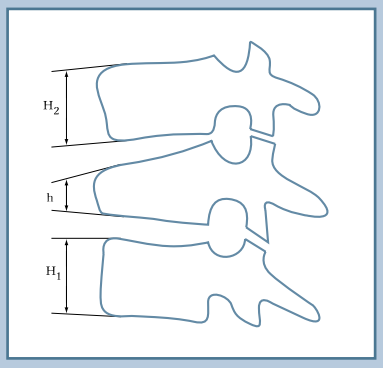

Fig. 3
Calculation of the degree of compression of a vertebral body according to Vinz [21]

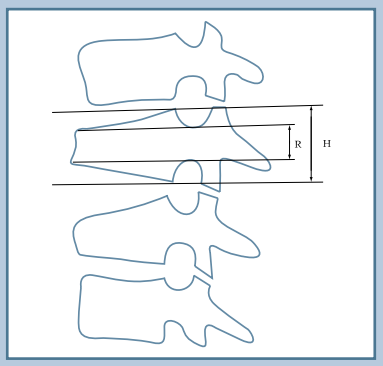

Fig. 4
Calculation of the wedge index of a vertebral upon compression fracture of the adjacent vertebrae:
H – height of the dorsal contour;
R – height of the ventral contour

Table 4

Distribution of study group patients with respect to severity of the pain syndrome according to the VAS scale at different stages of treatment, n (%)

Severity of the pain syndrome	Treatment duration		
	upon admission	after using the orthosis for 1 week	after using the orthosis for 2 weeks
No pain (VAS score 0)	1 (3)	26 (81)	32 (100)
Mild pain (score 1–3)	4 (13)	6 (19)	–
Moderate pain (score 4–6)	23 (71)	–	–
Severe pain (score 7–10)	4 (13)	–	–

Table 5

Distribution of control group patients with respect to severity of the pain syndrome according to the VAS scale after treatment, n (%)

Severity of the pain syndrome	After treatment
No pain (VAS score 0)	109 (76)
Mild pain (score 1–3)	23 (17)
Moderate pain (score 4–6)	9 (6)
Severe pain (score 7–10)	2 (1)

ance for the principle of three-point pressure control. A thoracic pad is used instead of the infraclavicular pads; it is positioned starting from the lower edge of the costal arch, along the midclavicualr line, up to the middle of the sternum. A suprailiac–pubic pad is used instead of the ventral one; it imposes pressure on the anterosuperior iliac horns and the pubic symphysis. In order to improve subjective feelings of a patient, these pads were immobilized using a 10 mm thick Isolon insert. The outer shell of the brace (the closed pelvis) is formed. The mechanism of action of the brace contributes to an increase in lumbar lordosis and displacement of the load on intervertebral joints.

The hyperextension brace for the thoracic spine [13] is used in patients with injured anterior portions of vertebral bodies at the T5–T12 level. Paravertebral pads are positioned at the level of the vertebra lying right below the injured one; the anterior pads, in the infraclavicular and the pubic regions.

The combined brace system for the thoracic and lumbar spine is used in patients with combined injury to the anterior portions of the bodies of thoracic and lumbar vertebrae. The sacral and lumbar parts of the brace are similar to those in the hyperlordosing brace, while the paravertebral pads are made longer to ensure better reclination of the thoracic spine. Infraclavicular pads in the infraclavicular fossae and the suprailiac-public pad are positioned along the ventral surface of the brace; the latter one applies pressure on the anterosuperior iliac horns and the pubic symphysis.

Calculations for the study group were performed using the X-ray images recorded on the day when patients sought help and 3, 6, 12, and 24 months after treatment had been started. For the control group, calculations were performed using the X-ray images recorded on the day when the patients sought care and 6, 12, and 24 months after treatment had been started. The results of the study are listed in Table 6.

In study group patients, the initial degree of compression of a vertebra was 63%; the WI was 0.6–0.8. These indices attested that vertebral injury in this group of children was more severe compared to the control group patients, where the degree of compression was 75 % and the WI fluctuated within the range of 0.75–0.9. Although the study group patients had a shorter length of stay and an extended range of locomotor activity allowed, consolidation and restoration of vertebral bodies in the study group took place better and faster than in the control group over equal periods of time.

Figs. 9, 10 shows the outcomes of conservative treatment of a 7-year-old female patient with compression fracture of lumbar vertebrae using early functional orthotic intervention.

Fig. 5
A hyperextension brace for the upper thoracic spine with the semi-rigid head support

It is clear from Table 6 that at equal periods of time that passed since the injury, the degree of compression of the vertebral body measured according to Vinz in control group patients remained smaller than that in the study group. Furthermore, the increase in the WI, up to restoration of its anatomic shape, occurred faster in patients in the study group compared to the control group patients. Despite the significant severity of injury in study group patients, vertebral body height restoration took place at a same pace as in patients with minor vertebral injuries. It should also be mentioned that no compressed vertebrae were detected in patients in the control group with the same degree of compression (63 %) and WI of 0.6–0.8; however, the rate of restoration of the damaged vertebrae was even lower.

An analysis of these results has demonstrated that in patients who had undergone a course of the conventional conservative therapy for treating vertebral compression fractures, the restora-

Fig. 6
A hyperlordosing brace for the lumbar spine

Fig. 7
A hyperextension brace for the thoracic spine

Fig. 8
A combined brace for the thoracic and lumbar spine

tion of shape and height of the anterior column of the body of an injured vertebra occurred within 12 months after the injury; the body height of the compressed vertebra subsequently remained unchanged and the vertebra retained its partial wedge-like shape. Meanwhile, the shape and height of the anterior column of the body of an injured vertebra were restored within 6 months when the actively correcting braces were used. The brace subsequently provided the optimal conditions for normal growth and development of the spine as confirmed by X-ray follow up examination 6–12 months after cessation of the orthosis use. The favorable conditions when wearing a brace contributed to formation of the physiological profiles of the spine and a correct posture stereotype.

Table 7 demonstrates that the frequency of positive outcomes of treating vertebral compression fractures using hyperextension braces (90.5 %) is higher than that achieved by using the conventional procedure (39.0 %). Restoration of the height and shape of an injured vertebral body was observed in 90.5 % of study group patients. In 9.5 % of patients, the incomplete restoration of vertebral body height is related to the failure to follow the orthopedic regimen. The pathological wedge-shaped deformity of vertebral bodies after the conservative treatment was observed in 48 % of control group patients. Only 76 % of patients did not complain of pain. An analysis of the results demonstrates that in 61 % of patients after a complete course of in-hospital and rehabilitation treatment, the procedure being used failed to completely unload the injured functional spinal unit and restore the anatomic shape and height of the injured vertebral body.

As a result, locomotor dysfunction manifesting itself as limited forward inclination of the body and an acute pain during jumping was observed in 24 % of patients in the late follow-up period. These patients sought help at various health facilities and rehabilitation centers complaining of back pain when making sudden bending movements or jumps or being exposed to long-lasting static load in order to undergo another course of conservative rehabilitation.

Fig. 9
Lateral X-ray and an MR image of the lumbar spine of a 7-year-old female patient S.: the wedge index of L3 = 0.8; L4 = 0.6

Conclusions

Hence, our study has proved that treatment of pediatric patients with compression fractures of the thoracic and lumbar vertebrae using early functional orthotics is more effective. Wearing braces is recommended for this group of patients starting from 10 days after the injury, after the pain syndrome is eliminated. The objective of treatment using the orthosis is to enable earlier verticalization of patients and ensure unloading, reliable fixation, and reclination of the injured functional spinal unit.

Application of hyperextension braces shortens hospital stay, eliminates the need for the subsequent long-term rehabilitation, contributes to complete restoration of height and shape of a damaged vertebral body, and allows children to earlier return to a familiar social environment.

Fig. 10
X-ray of the 7-year-old female patient S. after wearing the hyperextension brace for 6 months

Table 6

Comparative data on the degree of compression and the wedge index of the injured vertebra in the study and control groups at different stages of treatment

Group	Time when the control X-rays were recorded	Degree of compression measured according to Vinz, %	Wedge index
Study	Upon admission	63–90	0.60–0.80
	After 3 months	73–95	0.70–0.85
	After 6 months	81–98	0.75–0.90
	After 12 months	88–98	0.80–0.95
	After 24 months	93–100	0.90–1.00
Control	Upon admission	75–92	0.75–0.90
	After 6 months	78–94	0.83–0.95
	After 12 months	80–94	0.88–0.95
	After 24 months	80–94	0.88–0.95

Table 7

The treatment outcomes two years after the injury, n (%)

Outcome	Control group	Study group
No complaints of pain; X-rays show recovery of height and shape of the injured vertebrae	56 (39.0)	29 (90.5)
X-rays show the retained wedge-shaped vertebrae; no pain syndrome	53 (37.0)	3 (9.5)
Pain syndrome in the fracture area	19 (13.0)	–
X-ray show the retained wedge-shaped vertebrae; pain syndrome	15 (11.0)	–

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Received 02.02.2016
Review completed 17.03.2016
Passed for printing 05.04.2016

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