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CLINICAL STUDY

The effect of lengthening of the percutaneous implant in the surgical treatment of Th-L ankylosed spine fractures: 4 segment fixation versus 5 to 8 segment fixation

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ABSTRACT

BACKGROUND: Fractures of thoracolumbar spine in the field of ankylosing diseases such as ankylosing spondylitis (AS) and diffuse idiopathic skeletal hyperostosis (DISH) can by surgically treated with miniinvasive posterior transpedicular fixation. The exact length of implant is the subject of several studies. In our study, we retrospectively evaluated the treatment of B3 fractures of the ankylosed thoracolumbar spine with use a shorter versus longer implant, always with 8 screws.

METHODS: A total of 46 patients were included in the study (36 men and 10 women). Sixteen patients had AS and 30 patients had DISH. Patients treated between 2018 and 2022 with minimally invasive dorsal transpedicular fixation using 8 transpedicular screws were included in this study. We compared two groups where the first consisted of patients operated on with fixation of a maximum of 4 segments and the second group of patients consisted of patients in whom longer stabilization was used, at least 5 to 8 segments, with skipping of some vertebra between screws. We compared the effect of fixation length on reduction and retention before surgery, after surgery, and after 6 and 12 months. We evaluated the effect of reduction and retention on the basis of differences in the measurement of the Cobb angle and the angle, which we called "vege", which was formed by dislocation of the fracture. Furthermore, we monitored demographic data, the length of surgery, the number of complications, the number of concomitant injuries, the presence of a neurological deficit, and the result was assessed by the AO Spine PROST questionnaire.

RESULTS: In the entire group of 46 patients, the difference in the "vege" angle was significant ($p<0.001$). When comparing the reduction between the groups with short and longer fixation, the difference was not significant ($p=0.829$). The difference of the Cobb angle before and after the surgery in the comparison between the two groups did not show a statistically significant difference ($p=0.434$). Measurements of the Cobb angle bisegmentally after 6 and 12 months showed a progressive change in terms of kyphotization, which was smaller in the group with longer fixation, this difference was not statistically significant ($p=0.709$). Complete reduction was achieved in the group with short fixation vs 75% vs 63.3% with longer fixation (p-0.739). At the check-up after 6 months, all incomplete intraoperative reductions were spontaneously reduced.

CONCLUSIONS: Based on this study, we could conclude that both used constructions are comparable in terms of treatment results. It can be observed that longer fixation is more resistant to kyphotization at 6 and 12 months, but we would need a larger group of patients to confirm this hypothesis. In all incomplete reduced fractures through the surgery, complete reduction after verticalization occurred within 6 months in both groups. The angle of reduction was greater in the group with longer fixation, but the difference was not significant *(Tab. 6, Fig. 8, Ref. 31)*. Text in PDF www.elis.sk

KEY WORDS: ankylosing spondylitis, diffuse idhiopathic skeletal hyperostosis, spine fracture, ossifying diseases of the spine, treatment of fractures.

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Introduction

Fractures of the thoracolumbar spine in the field of ankylosing disease such as AS and DISH requires a special approach in diagnosis and treatment due to a significant change in the biomechanical properties of the spine. AS and DISH gradually lead to fusion of the mobile parts of the spine. The mobile spine gradually becomes immobile, rigid and fragile prone to fractures. The biomechanics of the spine changed in the way of AS and DISH is similar to a long bone (1, 2). Fusion of the mobile segments of the spine is a conse-

quence of ossification mainly of the intervertebral discs in AS and ossification primary of the anterior longitudinal ligament in DISH (1, 3, 4). Fractures are highly unstable with a high risk of spinal cord injury. The gold standard for the treatment of these fractures is surgical treatment. The first choice is dorsal transpedicular fixation. Today, it is mostly mini-invasive (5, 6–8). The exact length of fixation and the number of fixed segments is not included in the treatment recommendations today. The recommended length of fixation in the literature ranges from at least 2 segments above and 2 below the fracture to 3 above and 3 below and more, in various configurations (9–12). In a study from Robinson Y. they tested, in a computer simulation, the biomechanical differences of configurations from 1+2 segments, 2+2 segments, 3+3 segments (12). Some theories are based on the biomechanical properties of long bone osteosyntheses. Because the mechanical characteristics of spinal fractures in ankylosing terrain are similar to long bone osteosyntheses and are relatively well documented (14–18). In the works dealing with the osteosynthesis of long bones with LCP plates, it is stated that most of the failures of the surgical treatment of the fracture are caused by an inappropriate configuration of the implant in terms of sufficient length, location, and positions of the screws (19). The degree of rigidity or flexibility of the fixation has an impact on the healing of the fracture itself. The use of an LCP plate that is long enough to have several open holes above and below the fracture provides the desired elasticity of the construct, leading to a better healing of the fracture and a lower percentage of osteosynthesis failure (18). In this study, we aimed to evaluate and compare the radiological, demographic and outcome results in patients with fracture of ankylosed Th-L spine treated with a shorter maximum 4 segments miniinvasive dorsal transpedicular fixation and a longer 5 and more segments fixation.

Material and methods

In our study, the surgical treatment of patients with a type B3 fracture of thoracolumbar spine in the field of ankylosing disease such as AS or DISH was evaluated retrospectively. Primary goal was to compare two groups of used fixations. The first is a standard transpedicular insertion of 8 screws into the surrounding vertebrae, fixing a maximum of 4 segments (Figs 1, 2) The second is the use of a longer structure also using 8 screws but with skipping several segments between individual screws where we fix 5 or more segments (Figs 3, 4).

Inclusion criteria:

- B 3 fractures of thoracolumbar ankylosed spine treated with miniinvasive dorsal transpedicular fixation.

Exclusion criteria:

- Other type of spine fracture,
- Conservative treatment,
- Tumors, pathological fractures,
- Fractures of C-spine,
- Multiple fractures of the ankylosed spine.

In this study, we retrospectively evaluated 46 patients (16 AS and 40 DISH), 36 men and 10 women. 16 had the diagnose AS and 40 DISH. In the first group with short fixation, we had 16 patients and in the second group 30 patients. The average age of men was 67.4±10.2 and women 80.6±4.8 (<0.001). The mortality in hole group was 15 patients (32.6%). Neurological

Fig. 1. CT after injury.

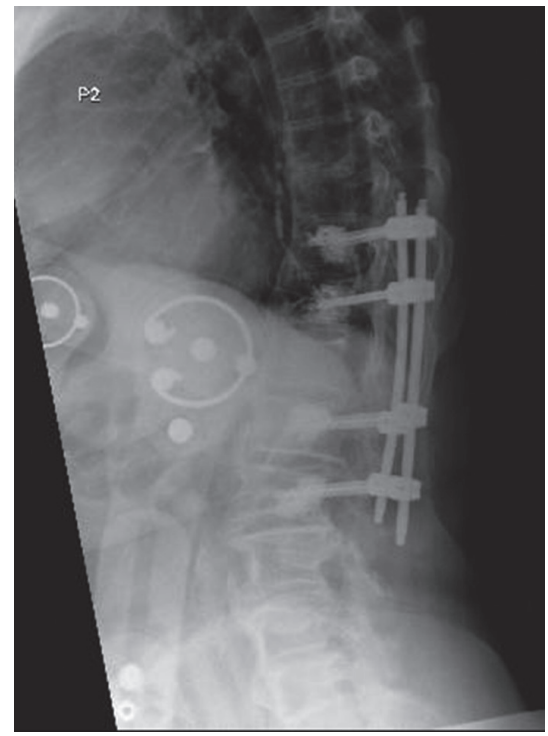

Fig. 2. X-ray after surgery with 4 segments fixation.

Fig. 3. CT after injury.

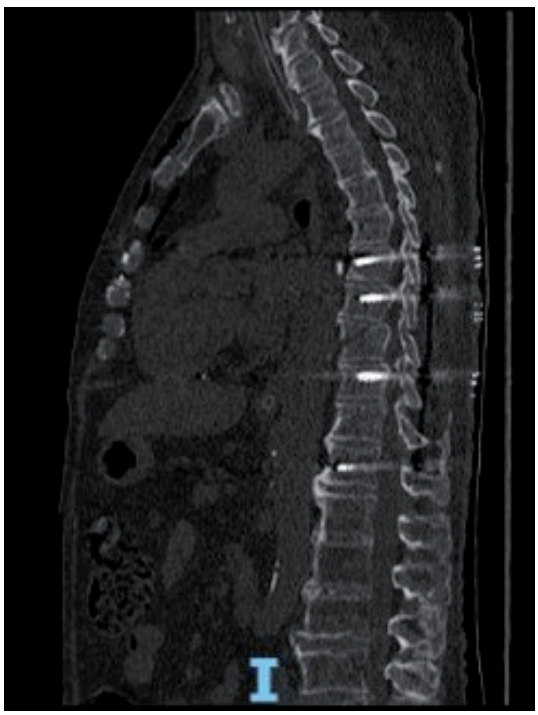

Fig. 4. X-ray after surgery with 5 segments fixation.

deficit was noted in group with short fixation once (6.6%) and in the group with longer fixation we had 3 patients (10%). Iatrogenic caused neurological deficit was present in one case (2.17%). In the entire set of 46 patients, concomitant injuries had 16 patients

Fig. 5. Mini-invasive transpedicular fixation – surgery technique.

(34.78%). Rib fractures were present in 15, hemothorax 8, pneumothorax 7 cases. Some patients had more than one concomitant injury. From intrahospital complications two patients had uroinfekt, 3 pneumonia and cardiopulmonary decompensation. One patient had atrial fibrillation, one presence of enterorhagia and one respiratory insufficiency. Infectious complications in surgical wounds were not present. The average duration of the surgery in the group of patients with fixation up to 4 segments was 81 minutes (40–185) with fixation of 5 or more segments 83 minutes (55–180). In the group with fixation of 3–4 segments, screw augmentation was used in 4 of 16 patients (34.7%), and in the group with fixation of 5–8 segments, in 4 cases out of 30 patients (13.3%) of cases.

Surgical technique

All the fractures in both groups were treated with dorsal minimally invasive transpedicular fixation with a dorsal approach using the Viper 2 MIS Spine System with 5.5 mm rods in prone position under X-ray control (Fig. 5). In osteoporotic bone we used augmented screws (Fig. 2). In the first group with shorter fixation, we skipped only the fractured vertebra or intervertebral disk (Fig. 2). In the group with long fixation, we skipped one or more vertebra between the screws (Fig. 4).

Radiological and clinical evaluations

The measurement of the Cobb angle, which was measured bisegmentally around the fracture, was used to quantify the change of axis in the sagittal plane after injury, after surgery, after 6 months and after 1 year after surgery (Fig. 6). Subsequently, the difference in the angles measured before and after the surgery and

Fig. 6. Measurement of Cobb's angle.

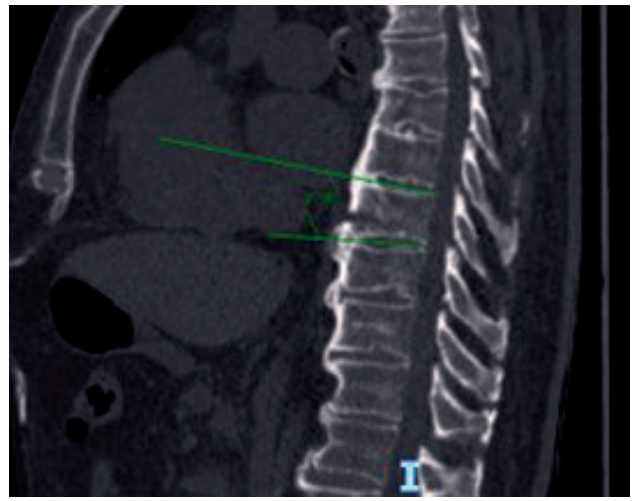

Fig. 7. Measurement of the vege angle in a fracture passing through the body of a vertebra.

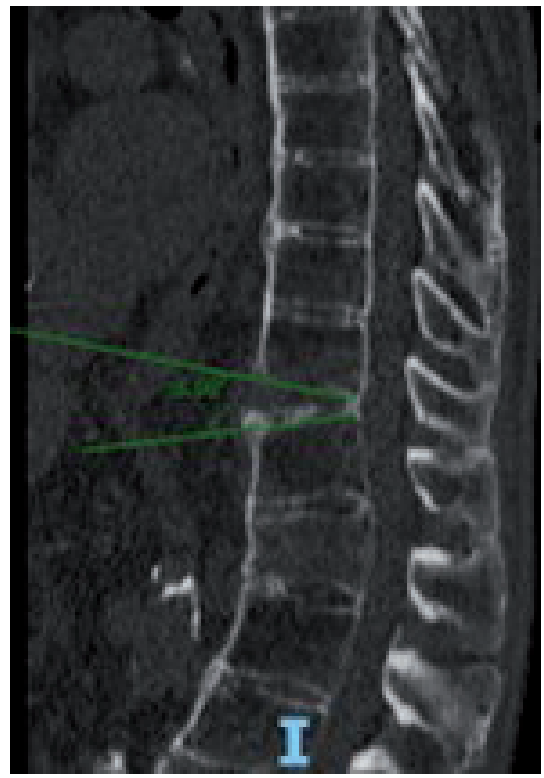

Fig. 8. Measuring the vege angle when the fracture passes through the disc.

then 6 months and 12 months after the surgery was calculated and compared in both groups. We measured also a "vege" angle that is formed by the gap at the location of the fracture either in the vertebral body or the intervertebral disc before and after the surgery (Figs 7, 8). We compared the difference of the angle in these two groups. We evaluated patient outcomes in individual groups with the AoSpine PROST questionnaire validated in the Slovak language (20).

Statistics

To evaluate the results of a retrospective study, patients were analyzed using SPSS version 29 (IBM Corp., Chicago, USA). Quantitative data was reported as arithmetic mean, standard deviation, error of the mean difference, or 95% confidence interval. Nominal data was reported such as frequencies and relative representation from the whole population (%). Significance of differences in quantitative values was tested using a t-test for independent sets or a paired t-test. Statistical significance of time differences was estimated using Mixed model ANOVA with repeated measures and pairwise comparisons with Bonferroni correction. Differences in nominal data were assessed according to the c2 goodness-of-fit test or Fisher's exact test (for the number of observations $n<5$). A significance level of $p<0.05$ (two-sided test) was considered statistically significant.

Results

Assessment of reduction of the fracture

The Cobb angle measured bisegmentally when comparing the situation before and after the operation did not show a statistically significant difference, while the vege angle before and after the surgery was statistically highly significant (t-test for paired data, $p<0.001$) (Tab. 1).

The difference in the vege angle when comparing the two measured groups with longer and shorter fixation was not statistically significant (Tabs 2, 3).

Tab. 1. Difference in measured angles before and after surgery.

Measure	Before treatment	After treatment	Mean dif (95% CI)	p
Cobb angle	8.41 (5,63)	7.87 (5.46)	0.54 (–0.84; 1.93)	0.434
Vege	–3.86 (7.55)	–1.28 (5.73)	–2.59 (–4.04; –1.13)	< 0.001

Tab. 2. Vege differences according to n spinal segment fixation – group statistic

Characteristics	N, segment fixation	Patients	Mean	SD
Vege differences	3 to 4	16	2.992	4.224
	5 to 8	30	3.282	4.376

Tab. 3. Unrelated samples t-test for Vege differences according to n spinal vertebrae fixation

Measure	t	df	p	Mean differenece	Std. error of difference	95% CI of the mean difference	
						Lower bound	Upper bound
Vege dif	–0.217	44	0.829	–0.290	1.339	–2.989	2.408

Out of these 46 patients, a complete reduction was achieved intraoperatively in approximately 70% of cases. The results of complete and incomplete reduction of the fracture in our two groups are in the table number 6. In both groups, after verticalization within 6 months, complete reduction occurred in all patients who came for a check-up (Tab. 4).

In the next follow-up, we measured whether there was a change in the Cobb angle measured bisegmentally after 6 and 12 months after the surgery. In both compared groups, there was a gradual change in the angle in the sense of gradual kyphotization. These differences were smaller in the group of patients with longer fixation, but the difference between the evaluated groups did not show a statistically significant difference (Tab. 5).

Tab. 4. Success rate of spinal vertebrae reposition according to n of fixed vertebrae

Reduction	3 to 4	5 to 8	p
Complete	12 (75)	20 (66.7)	0.739
Incomplete	4 (25)	10 (33.3)	0.739
Total	16 (100)	30 (100)	

Patient outcome was evaluated based on the AO Spine PROST examination. The results of patient's outcome are in Table 6. The difference in the outcome value did not show a statistically significant difference between the evaluated groups because we had only 7 PROST examinations in the group with short fixation and 8 in the group with longer fixation.

Discussion

AS and DISH are diseases that significantly change the biomechanical properties of the spine based on the gradual fusion of movable parts of the spine (1, 2, 21). Fractures in such altered terrain are highly unstable with a high percentage of neurodeficits (6, 9, 22). Due to the specific characteristics of these fractures, the gold standard of treatment is dorsal transpedicular fixation as soon as possible after the injury (7). In the literature, there is agreement on the use of multilevel fixation, but the length of fixation used in individual works is not the same (7, 10, 15, 23). There are works in the literature that compare the open method and the mini-invasive method of dorsal transpedicular fixation, where reduction and retention of fractures is comparable. The differences are in smaller blood losses, shorter surgery time, fewer infectious complications, shorter hospitalization in favor of mini-invasive systems (17, 23, 24).

Clinical studies comparing longer and shorter fixation of dorsal miniinvasive transpedicular fixation in the treatment of fractures in the field of ankylosing spondylitis were not found in the literature. A computer simulation evaluating the mechanical properties of the ankylosing spine and the properties of different configurations of dorsal transpedicular fixation suggests that 2+1 fixation was connected with a higher risk of failure. The use of a 2+2-segment configuration was less resistant to mechanical stress than a 3+3-segment configuration, but it was sufficient. Skipping

Tab. 5. Spinal segment fixation x time – pairwise comparisons. 1 is time after surgery, 2 is 6 months after surgery an 3 is 12 months after surgery.

Segment (I)	Time (J)	Time	Mean difference (I-J)	Std. error	p	95% CI for difference	
						Lower bound	Upper bound
3 to 4	1	2	1.179	2.388	1.000	–5.459	7.817
		3	0.073	2.476	1.000	–6.810	6.956
	2	1	–1.179	2.388	1.000	–7.817	5.459
		3	–1.106	0.613	0.290	–2.811	0.599
	3	1	–0.073	2.476	1.000	–6.956	6.810
		2	1.106	0.613	0.290	–0.599	2.811
5 to 8	1	2	–0.473	2.388	1.000	–7.111	6.165
		3	–0.949	2.476	1.000	–7.832	5.935
	2	1	0.473	2.388	1.000	–6.165	7.111
		3	–0.476	0.613	1.000	–2.181	1.229
	3	1	0.949	2.476	1.000	–5.935	7.832
		2	0.476	0.613	1.000	–1.229	2.181

a segment does not confer an advantage (12). The results of our clinical study were the use of a shorter fixation with 2+2 segmental fixation and a longer one with the skipping of one or more vertebrae using the same number of screws were similar. There were no differences in reduction or retention. Both methods of fixation can be used in the treatment of such fractures. Using always 8 screws was sufficient because we did not notice any failure of fixation. The unnecessary use of more screws is associated with higher costs, a higher risk of screw misplacement, and longer time of surgery and radiation exposure (25). The assessment of reduction was compared only between open and minimally invasive systems, where no significant differences were observed (24). As in Lindtner's work from 2017, in our work, patients with incomplete intraoperative reduction after verticalization had a complete reduction without failure of fixation (11).

The duration of the surgery was almost the same in both evaluated groups. In the literature, surgery duration ranges from 98 minutes to 227 minutes (7, 16, 23, 24). The different durations of surgery are related to the number of instrumented vertebrae. We used the same number of screws in both groups in this study. As a result, the duration of surgeries in both groups was comparable.

In the studied group, the ratio between women and men was comparable to data in other studies (26, 27).

If we omit the evaluation of the localization of fractures of the C spine injury from this study, the distribution of fractures in this set was comparable to the literature (5, 30).

The most common concomitant injuries were rib fractures. These concomitant injuries were related to the mechanism of injury. These injuries were also related to fusion of the costovertebral joints and rigidity of the entire ribcage. The distribution of fractures was probably related to the changed biomechanics of the ankylosing spine, the injury mechanism and the present hyperkyphosis of the thoracic region. In our group, neurological deficit was present at admission in 8.7% of cases. According to various works, the overall incidence of neurological deficit ranges from 17 to 81% (9). Such different percentages of the occurrence of neurological deficit in individual patients were related to the size of the individual sets, and if fractures in the cervical and cervicothoracic region were also included in the study, then the occurrence of neurological deficit increases.

The occurrence of pneumonia is comparable to the occurrence of pneumonia in a relatively large set of patients – 741 in the work of Schaefer, where it was present in 5.6% of cases. In Schaefer´s work, respiratory failure was present in 6.6% of cases (10). Fixation failure or tearout occurred in one case in this study – 2.2%. In the work of Schaefer, they describe failure of fixation in ankylosing spondylitis in 4.4% of cases and in DISH in 0.8% of cases (10). In the work of Craron et al the tearout occurred in 15% (9, 31).

Mortality within one year in the literature in comparable sets was different. It ranges from 24 to 33% (28, 29). Mortality within 1 month in our group was lower than reported in the literature, where, for example, it was 10.0% in the work of M. Schwendner (15). In-hospital mortality for spinal fracture was not recorded. In the work of Schaefer, the mortality during hospitalization for the fracture was 5.2% (10).

Tab. 6. Average values of AO Spine PROST.

	3–4 segments	5–8 segments
Average values of Ao Spine PROST	75.08%	63.73%

Conclusion

Based on this study, we could conclude that both used constructions are comparable in terms of treatment results. It can be observed that longer fixation is more resistant to kyphotization at 6 and 12 months, but we would need a larger group of patients to confirm this hypothesis. In all incomplete reduced fractures through the surgery, complete reduction after verticalization occurred within 6 months in both groups. The angle od reduction was greater in the group with longer fixation, but the difference was not significant.

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