Research Square

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Should the Level of the Posterior Instrumentation Combined With the Intermediate Screw Be a Short Segment or a Long Segment in Thoracolumbar Fractures With Fusion to the Fractured Segment?

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Research Article

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Abstract

Purpose

It was aimed to compare the results of long segment posterior instrumentation with intermadiate pedicular screw + fusion at the level of the fractured segment including one vertebra above and one below the fractured vertebra (LSPI) and short segment posterior instrumentation with intermadiate pedicular screw + fusion at the level of the fractured segment including one vertebra above and one below the fractured vertebra (SSPI) in the surgical treatment of thoracolumbar vertebral fractures.

Methods

90 patients with thoracolumbar vertebral (T11-L2) fractures operated between March 2015 and February 2022 were included in the study. The patients were divided into two groups as those who underwent LSPI (group A: n: 54, age: 40.3) and those who underwent SSPI (group B: n: 36, age: 39.7). Radiological evaluations like vertebral compression angle (VCA), vertebral corpus heights (VCH), intraoperative parameters and complications were compared between the groups.

Results

Correction in early postoperative VCA was statistically significantly better in Group A ($p = 0.003$). At 1-year follow-up, postoperative VCA correction was significantly more successful in group A ($p = 0.001$). There was no difference between the two groups in terms of correction loss in VCA measured at 1-year follow-up. There was no statistically significant difference between the two groups in terms of postoperative VCH, VCH at 1-year follow-up, and correction loss in VCH.

Conclusion

LSPI provides better postoperative kyphosis correction of the fractured vertebra than SSPI. Regarding of the segment level of posterior instrumentation, there was no difference between the two groups in terms of the loss of achieved correction of VCA, ABH, and PBH at 1-year follow-up. Operating a thoracolumbar fracture with LSPI will lengthen the operation and increase the number of intraoperative fluoroscopies compared to SSPI.

1. Introduction

The most frequent spine injuries are thoracolumbar fractures (T11-L2) [1]. This area is a significant biomechanical stress area because it marks the change from the rigid thoracic spine with the rib cage to the more dynamic lumbar spine. Neurological deficits occur in approximately 20% of patients after thoracolumbar vertebral fractures. As a result, it is a prevalent source of morbidity in the community [2].

Anterior, posterior or combined approaches are used in the surgical treatment of thoracolumbar fractures. The difference in approach depends on the experience of the surgeon. Posterior fusion stands out with its

short learning curve, short operation times and less blood loss. [3, 4]. In the surgery of thoracolumbar fractures with posterior fusion, long segment fusion provides more stable fixation, but leads to more mobile segment loss. Short segment fusion causes less mobile segment loss, but in long-term follow-up, it may cause implant failure and progressive kyphosis. It is still a matter of debate whether to use long segment or short segment in unstable fractures. Different studies report different results [5–7]. Short segment fusion is recommended in studies conducted in the last 5 years. However, the benefits of long segment fusion cannot be ignored.

When performing long segment and short segment fusion, it is debatable whether a screw should be placed on a fractured spine. Pedicular screw placement on the fractured vertebra improves stability and lowers load on the non-fractured vertebra, according to biomechanical studies [8]. Biomechanical studies point to intermediate screw fixation in the short section, with few studies on long segment fixation [7].

The aim of this study is to compare the results of long segment posterior instrumentation (consisting of pedicular screws, 2 levels above and below the fractured vertebra, with interconnected rods) with intermadiate pedicular screw + fusion at the level of the fractured segment including one vertebra above and one below the fractured vertebra by posterolateral/posterior allograft (LSPI) and short segment posterior instrumentation (consisting of pedicular screws, 1 level above and below the fractured vertebra, with interconnected rods) with intermadiate pedicular screw + fusion at the level of the fractured segment including one vertebra above and one below the fractured vertebra by posterolateral/posterior allograft (SSPI) in the surgical treatment of thoracolumbar vertebral fractures.

2. Materials and Methods

2.1 Study Design and Patient Characteristics

It was formed on patients who were operated with posterior instrumentation due to thoracolumbar vertebral fracture in the Orthopedics and Traumatology Department since the approval date of Medical Research Ethics Committee. Our study is a retrospective study. Before beginning study methods, the participant's informed consent was obtained.

Ninety patients with thoracolumbar vertebral (T11-L2) fractures operated between March 2015 and February 2022 were included in the study. The patients were divided into two groups as those who underwent LSPI (group A: n: 54, age: 40.3) and those who underwent SSPI (group B: n: 36, age: 39.7). We noted the patients' age, sex, level of injury, AO classification, mechanism of injury and ASIA (American Spinal Cord Injury Association) impairment scale (Table 1). The data obtained were compared among the groups.

Table 1
Demographic and clinical characteristics of the groups.

		Group A (LSPI) n = 54	Group B (SSPI) n = 36	t or $\varvec{\chi}^2$	*p*-value
Age		40.34 ± 14.72	39.73 ± 10.81	0.20	0.844
Gender, n (%)	**Female**	20 (37.04)	12 (33.33)	1.74	0.085
	Male	34 (62.96)	24 (66.67)		
Mechanism of İnjury, n (%)	**Motor vehicle**	12 (22.22)	8 (22.22)	0.10	0.917
	Failing	42 (77.78)	28 (77.78)		
Location of the fracture, n (%)	**T11**	5 (9.26)	1 (2.78)	1.09	0.279
	T12	16 (29.63)	11 (30.56)		
	L1	21(38.89)	14 (38.89)		
	L2	12 (22.22)	10 (27.77)		
AO Classification, n (%)	**A**	36 (66.67)	26 (72.23)	0.75	0.993
	A1	4 (7.41)	3 (8.33)		
	A2	5 (9.26)	2 (5.56)		
	A3	10 (18.52)	5 (13.89)		
	A4	17 (31.48)	16 (44.45)		
	B	18 (31.48)	10 (27.77)		
	B1	0	0		
	B2	18 (31.48)	10 (27.77)		
	B3	0	0		
	C	0	0		
ASIA impairment scale, n (%)	**A**	0	0	0.00	1.000
	B	0	0		
	C	0	0		
	D	12 (22.22)	8		

	Group A (LSPI) n = 54	Group B (SSPI) n = 36	t or $\varvec{\chi}^2$	*p*-value
E	42 (77.78)	28		

LSPI, long-segment posterior instrumentation (consisting of pedicular screws, 2 levels above and below the fractured vertebra, with interconnected rods) with intermediate screw + fusion at the level of the fractured segment; SSPI, short-segment posterior instrumentation (consisting of pedicular screws, 1 level above and below the fractured vertebra, with interconnected rods) with intermediate screw + fusion at the level of the fractured segment; ASIA, American Spinal Cord Injury Association; n, number.

Since estimating the screw length in a fractured pedicle with a tiny spherical tip probe used to confirm the length of the entrance hole would be challenging, placing the proper pedicular screw in a fractured vertebra could be difficult. Moreover, it can cause medial or lateral pedicle penetration during the insertion of the pedicular screw. In our study, the pedicles of the fractured vertebrae of all patients included in the study were intact.

2.2 Assessment of the Parameters Among Groups

During the surgery, the intraoperative parameters (instrumentation duration and intraoperative fluoroscopy number) were noted. Three orthopedic surgeons who took part in the research used the software Sectra to acquire and evaluate preoperative computed tomography (CT) and postoperative plain radiograph images (Sectra AB, Linkoping, Sweden). All the radiological images were assessed in a blinded fashion. Radiological images of the thoracolumbar spine were compared retrospectively pre-operative, one day after operation and 1-year follow-up. The fractures were classified according to the AO classification. Additionally, the following measurements were performed using pre-operative CT and standing plain radiographs [9].

1-Vertebral compression angle (VCA; defined as the angle between lower and upper border of fractured vertebra) (Fig. 1a-c, Fig. 2a-c)

2-Anterior body height (ABH; measured from the anterosuperior corner of the vertebra to the anteroinferior corner) (Fig. 1d-f, Fig. 2d-f)
3-Posterior body height (PBH; measured from the posterosuperior to posteroinferior corner) (Fig. d-f, Fig. d-f)

4-Anterior vertebral body compression percentage (ABH/PBH ratio)

2.3 Surgery

The surgeons decided to operate on patients with thoracolumbar vertebral fractures, if the posterior osteoligamentous complex is impaired, if the vertebral corpus kyphosis is greater than 25°-30°, if the vertebral corpus height loss is more than 50% or if there is more than 50% canal compression in the radiological evaluations. All surgeries were done when the patients' general condition permitted, all

radiological examinations were completed, and consultations were completed in the emergency department (< 48 hours). All patients underwent posterior instrumentation with intermadiate pedicular screw + fusion at the level of the fractured segment including one vertebra above and one below the fractured vertebra by posterolateral/posterior allograft under general anesthesia, with the posterior midline approach and the fractured vertebra centered using the Roy-Camille method (10,11). All surgeries were performed by two experienced surgeons (O.A., A.M.O.) using similar approach and implants except the level of the instrumentation. LSPI (group A) was preferred by surgeon 1, on the other hand, SSPI (group B) was preferred by surgeon 2 during surgery. According to surgeon 1 why to perform LSPI; long segment fixation has superiority in construct stability, which is important in fusion surgeries. Besides, using a longer precountered rod during surgery may help more in achieving correction of the kyphosis during surgery because the pedicular screws in the fractured vertebra biomechanically behave as a push point with an anterior vector, providing a more powerful lordosing force that corrects the kyphosis than short segment fixation [12, 13] (Figs. 3,4). In addition, short segment fixation has been shown to produce less favorable results in terms of kyphotic correction, correction maintenance, and implant failure when compared to long segment fixation in cases with poor anterior column support and lower mechanical stiffness, even when intermediate screws are used [14, 15]. Surgeon 2 was thinking in his decision that although long segment posterior fixation provides more stability and support with fewer risks of implant failure, it comes with the loss of motion segments. Long segment fixations have also been linked to greater movement in adjacent disc spaces, resulting in increased intradiscal pressure. These biomechanical impacts are known to accelerate the process of adcesent disc degeneration [16]. To overcome these limitations of long-segment fixation, he decided to operate with a short segment fixation technique incorporating the pedicle of fractured vertebrae. He believed that with intermediate screw in short segment fixation, the construct gains sufficient rigidity in fusion surgery.

2.4 Statistical Analysis

The frequencies and percentages were given for categorical variables; and the mean and standard deviation (SD) were given for numerical variables as descriptive statistics. Categorical variables were compared between groups with Pearson's Chi-squared test. Shapiro Wilk test was used to test normality assumption in numerical variables. Group comparisons for numerical variables were performed with independent sample t-test. The change in radiological outcomes was analyzed by repeated measures analysis of variance (ANOVA) in each group. The Intraclass correlation coefficient (ICC: Two-way mixed effects, absolute agreement, three raters) was used to analyze interrater reliability at each measurement time point.

Statistical significance was assessed at $p < 0.05$, and all statistical analyses were performed using IBM SPSS Statistics 23.0 (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.)

3. Results

There was no statistical difference with respect to age, sex, mechanism of injury, level of injury, AO classification of the fracture and ASIA impairment scale between the groups (Table 1).

The radiological examinations were made by three different experienced orthopedic surgeons at three assessments. The ICC values were 0.989, 0.984, 0.991 for VCA, 0.994, 0.993, 0.992 for ABH and 0.996, 0.989, 0.995 for PBH according to the time schedule of measurements.

The results of the radiological evaluations were shown in Table 2. Both groups significantly restored VCA and VBH's (vertebral body height) after operation ($p < 0.001$). There was no significant difference in pre-operative VCA ($p = 0.849$). Correction in early postoperative VCA was significantly better in Group A ($p = 0.003$). At the 1-year follow-up, postoperative VCA correction was significantly more successful in group A ($p = 0.001$). There was no difference between the two groups in terms of correction loss in VCA measured at the 1-year follow-up. There were no significant differences in pre-operative ABH, post-operative ABH, 1-year follow-up ABH, correction loss ABH, pre-operative PBH, post-operative PBH, 1-year follow-up PBH, correction loss PBH, pre-operative ABH/PBH ratio, post-operative ABH/PBH ratio and 1-year follow-up ABH/PBH ratio among the groups ($p = 0.121$, $p = 0.129$, $p = 0.136$, $p = 0.234$, $p = 0.129$, $p = 0.125$, $p = 0.109$, $p = 0.444$, $p = 0.418$, $p = 0.282$ and $p = 0.153$ respectively).

Table 2
Radiological and intraoperative parameters of the groups.

	Group A (LSPI) n = 54	Group B (SSPI) n = 36	t	p-value
Pre-operative VCA (°)	12,29 ± 5.70	12.07 ± 5.49	0.19	0.849
Post-operative VCA (°)	4.69 ± 3.51	7.08 ± 3.86	3.11	0.003*
1-year follow-up VCA (°)	5.58 ± 3.12	8.30 ± 4.64	3.44	0.001*
Correction loss VCA (°)	1.19 ± 1.57	1.59 ± 2.20	1.03	0.305
Pre-operative ABH (mm)	15.84 ± 3.84	17.04 ± 3.43	1.56	0.121
Post-operative PBH (mm)	30.05 ± 3.01	31.10 ± 3.58	1.55	0.125
1-year follow-up ABH (mm)	25.02 ± 3.20	26,24 ± 4.49	1.50	0.136
Correction loss ABH (mm)	1.27 ± 1.44	1.68 ± 2.00	1.20	0.234
Pre-operative PBH (mm)	22.87 ± 3.76	24.01 ± 3.07	1.53	0.129
Post-operative PBH (mm)	30.05 ± 3.01	31.10 ± 3.58	1.55	0.125
1-year follow-up PBH (mm)	29.31 ± 2.92	30.28 ± 2.73	1.62	0.109
Correction loss PBH (mm)	1.30 ± 1.18	1.08 ± 1.55	0.77	0.444
Pre-operative ABH/PBH ratio	0.69 ± 0.11	0.71 ± 0.10	0.81	0.418
Post-operative ABH/PBH ratio	0.86 ± 0.09	0.84 ± 0.13	1.08	0.282
1-year follow-up ABH/PBH ratio	0.86 ± 0.08	0.82 ± 0.12	1.44	0.153
Operation time (min)	155.08 ± 13.42	104.86 ± 14.81	17.31	< 0.001*
Fluoroscopy number (n)	25.18 ± 2.20	15.46 ± 2.13	53.43	< 0.001*

LSPI, long-segment posterior instrumentation (consisting of pedicular screws, 2 levels above and below the fractured vertebra, with interconnected rods) with intermediate screw + fusion at the level of the fractured segment; SSPI, short-segment posterior instrumentation (consisting of pedicular screws, 1 level above and below the fractured vertebra, with interconnected rods) with intermediate screw + fusion at the level of the fractured segment; ABH, anterior body height; PBH, posterior body height; (°), degrees; mm, millimeter; min, minute; n, number; *, significant.

There was a significant difference in operation time and intraoperative fluoroscopy numbers in group A (155.08 ± 13.42 min, 25.18 ± 2.20 times) compared to group B (104.86 ± 14.81 min, 15.46 ± 2.13 times) ($p < 0.001$, $p < 0.001$ respectively) (Table 2).

Following surgery, all patients have effective solid posterior spinal fusion. Early superficial tissue infection was observed in one patients (1.85%) in group A and treated effectively with oral antibiotic.

Implant failure occurred in two patients (3.70%) in group A and one patient (2.78%) in group B.

4. Discussion

The most striking result of our study is that although LSPI provides better postoperative correction of the fractured vertebra than SSPI, there is no difference between the two groups in terms of loss of gained correction in the 1-year follow-up.

It is controversial whether pedicle screws in the fractured vertebra should be used for short segment fixation or long segment fixation in the treatment of thoracolumbar vertebral fractures performed with a posterior approach [17, 18]. Numerous studies on this topic can be found in the literature. Pedicle screw placement in the fractured vertebra in short segment posterior instrumentation is recommended by many authors and is almost out of discussion. Studies have focused on short segment fusion where screws are placed on the fractured vertebra and long segment fusion where no screws are placed on the fractured vertebra. Our study is important because there are few studies comparing short segment posterior instrumentation combined with intermediate screw and long segment posterior instrumentation combined with intermediate screw.

Short-segment instrumentation offers the advantage of involving fewer motion segments in fusion but may not provide adequate long-term stabilization. Negative effects of short-segment instrumentation have been reported in the literature [19, 20]. It is important that the use of pedicle screws in the fractured vertebra are functional, so the choice of short-segment fusion is not appropriate for every patient. On the other hand, although posterior long-segment instrumentation provides more stable fixation and less correction loss on follow-up, it reduces the number of mobile vertebrae because it involves multiple segments and results in increased operative time, blood loss and fluoroscopy number.

Tezeren et al. [21] showed that posterior instrumentation with long segment produced better radiographic results, although no difference was found between the two groups in terms of clinical outcomes when comparing short and long segment instrumentation without intermediate screw. Aly TA et al. [22] compered short segment versus long segment pedicle screws fixation in his meta-analysis and he showed that no significant difference was identified between the two groups regarding radiological outcome, functional outcome, neurologic improvement, and implant failure rate.

The intermediate screw fixation technique, introduced in 1994 under the direction of Dick et al, offered a new perspective for the treatment of thoracolumbar forty. In a biomechanical study, it was shown that insertion of screws into the fractured vertebra stabilized the fracture and reduced the loss of correction [23–26]. Clinical studies have shown that fixation of the fractured vertebra with a pedicle screw during posterior short-segment instrumentation stabilizes the fracture and that there is no change in kyphosis at follow-up [27–29].

Dobran et al. [27] compared instrumentation of the long segment without screws at the fractured vertebra and instrumentation of the short segment with screws at the fractured vertebra and they demonstrated

similar correction of kyphosis and preservation of sagittal alignment at follow-up. Guven et al. [29] compared 4 groups with intermediate screws and without intermediate screws posterior short-segment and long-segment fusion. It was found that long-segment fusion with a intermediate screw provided the best results at follow-up. In our study, correction in early postoperative VCA was statistically significantly better in Group A ($p = 0.0025$). There was no difference between the two groups in terms of correction loss in VCA measured at 1-year follow-up. There was no statistically significant difference between the two groups in terms of postoperative VCH, VCH at 1-year follow-up, and correction loss in VCH. There is no difference between the two groups in terms of loss of correction during the 1-year follow-up, despite the fact that long segment fusion offers superior postoperative correction of the fractured vertebra than short segment fusion.

Biomechanically, it has been shown that intermediate screws in the fractured vertebra can act as a repulsion point for an anterior vector, resulting in a lordotic force that also corrects kyphosis in the segment [12]. The three-point fixation afforded decreases the cantilever effects that cause kyphosis. The screw head of the pedicle screw in the fractured vertebra serves as the fulcrum for this forward thrust, which causes compression behind the screw head and distraction anteriorly. With this mechanism, when the appropriately precontoured rod is placed on the pedicular screws during indirect reduction, the pedicular screw in the fractured vertebrae acts as a pressure point, increasing the forward force and providing more effective lordosis of the collapsed segment [13]. We found in our study that the correction in early postoperative VCA was significantly better in Group A ($p = 0.003$). Furthermore, at 1-year follow-up, postoperative VCA correction was significantly more successful in group A ($p = 0.001$). Since we use a longer precontoured rod in group A, it may act more effectively as a push point to increase forward force on fractured vertebrae by providing a more powerful lordosing effect with a longer anterior vector arm at the time of indirect reduction of the fracture during surgery.

The removal of implants after satisfactory fusion of thoracolumbar fractures may be useful in regaining flexibility and eliminating pain, but it also has the potential to result in complications after surgery. Both operators and their patients must be informed of the indications necessitating implant removal and have realistic expectations on the advantages and hazards. There was insufficient evidence to support routine removal of pedicle screw tools following complete fusion of thoracolumbar fractures, which could expose patients to avoidable risks like infection and costs [30]. Although there are discussions, it is not recommended to remove the implant in the literature, especially in cases with short segment posterior instrumentation + fusion since the fusion occurs throughout the construct segments. Because there will be no movement in the fusion segments following solid fusion, the stress on the fixation during movement will be reduced, hence the risk of implant failure. On the other hand, in patients in the LSPI group, the stress on the screw and rod in the non-fused areas continued with movement. Therefore, implants were removed after 1 year in patients in the LSPI group, while implant removal surgery was not performed in patients in the SSPI group. This can be defined as a disadvantage of preferring LSPI as a treatment for thoracolumbar fractures. The implant removal was suggested to the group A after 1 year postoperatively due to the possibility of implant failure, which invalidated the hardware removal comparison between the groups. In our study, implant failure occurred in two patients in group A and one

patient in group B. The implant removal was performed after a 1-year follow-up in patients in group A. However, for some patients who participated in the study, this period was longer due to the patient's social status or excuse. Since the fusion was made only at the fractured vertebral level, bending and twisting forces may have continued in pedicle screws and rods located above and below the fusion site. Therefore, we think that a fracture was detected in one of the lowest screws in two patients in group A. Screw breakage was connected with a history of direct trauma in the patient in group B.

Due to the fact that more segments are implanted in patients operated on with LSPI, in accordance with the literature, the operation time and the number of fluoroscopy were found to be higher in group A compared to group B in our study [5–7, 21, 22, 27]. This can be shown as another disadvantage of preferring LSPI as a treatment for thoracolumbar fractures.

Some limitations could be noted in this study. It was a retrospective study. A larger patient population is needed for further assessment. Postoperative results of fractures in the thoracolumbar region, rather than a single fracture type, were compared. Instead of comparing the outcomes of operations performed by a single surgeon, we made a comparison between groups by including patients with thoracolumbar fractures who were operated on by two experienced surgeons working in two different university hospitals in the same province. The idea of the adcesent segment degeneration was not evaluated in this study. During radiological evaluations, it was difficult to identify the endplate in cases with heavily comminuted and collapsed fractures. The implant removal was suggested to the group A after 1 year postoperatively due to the possibility of implant failure, which invalidated the hardware removal comparison between the groups.

5. Conclusion

LSPI provides better postoperative kyphosis correction of the fractured vertebra than SSPI. Regardless of the segment level of posterior instrumentation, there was no difference between the groups in terms of loss of the achieved correction of VCA, ABH and PBH in the 1-year follow-up. Operating a thoracolumbar fracture with LSPI will lengthen the operation and increase the number of intraoperative fluoroscopies compared to SSPI. The need for implant removal in the LSPI group can be defined as a disadvantage of preferring LSPI as a treatment for thoracolumbar fractures.

Declarations

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Authors' contributions: Each author made substantial contributions to the following components of the project: conception, design, interpretation of data, drafting of the manuscript. All authors read and approved the final manuscript.

Conflict of interest: No financial conflict of interest exists with any commercial entity whose products are described, reviewed, evaluated or compared in the manuscript. None of the authors hold any financial

interest in the products, devices or drugs mentioned in this article. We declare that this article, in whole or in part, has not been presented or published elsewhere and is original work.

Author Contribution

Concept: O.S., O.A., A.M.O.Design: O.S., S.A., B.K., A.M.O.Supervision: O.S., O.A., A.M.O.Materials: O.S., S.A., B.K., A.M.O.Data Collection and/or Processing: O.S., S.A., B.K., A.M.O.Analysis and/or Interpretation: O.S, O.A., A.M.O.Literature Search: All authorsWriting: All AuthorsCritical Review: O.S., O.A., A.M.O.

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Figures

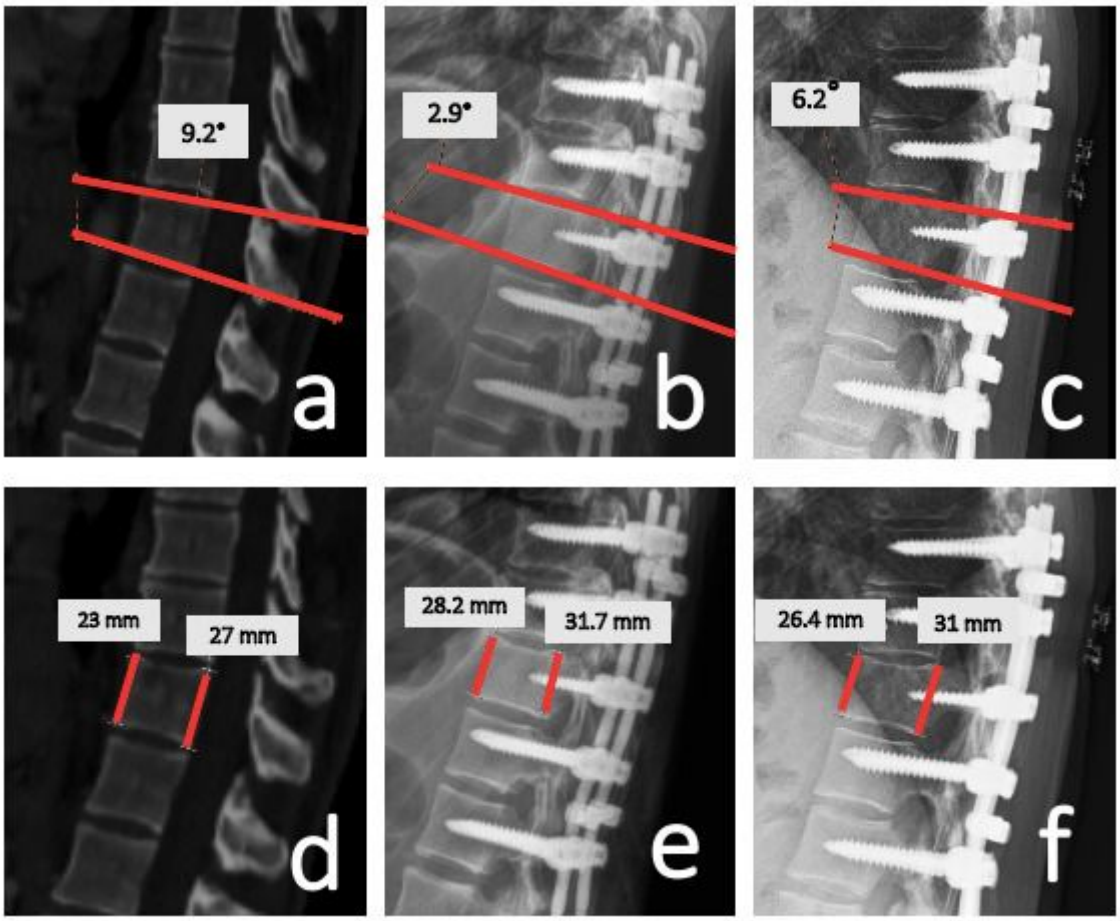


Figure 1

Vertebral compression angle (VCA) measurement pre-operative (**a**), early post-operative (**b**) and 1-year follow-up (**c)** in group A. Anterior body height (ABH) and posterior body height (PBH) measurements pre-operative (**d**), early post-operative (**e**) and 1-year follow-up (**f)** in group A.

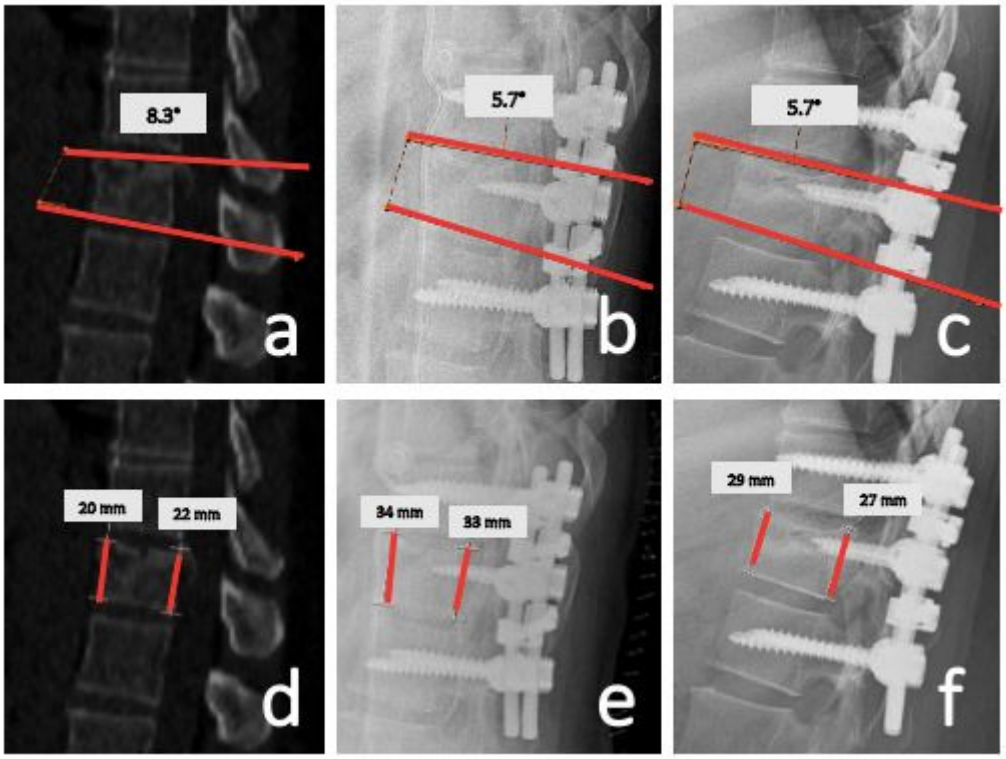


Figure 2

Vertebral compression angle (VCA) measurement pre-operative (**a**), early post-operative (**b**) and 1-year follow-up (**c)** in group B. Anterior body height (ABH) and posterior body height (PBH) measurements pre-operative (**d**), early post-operative (**e**) and 1-year follow-up (**f)** in group B.

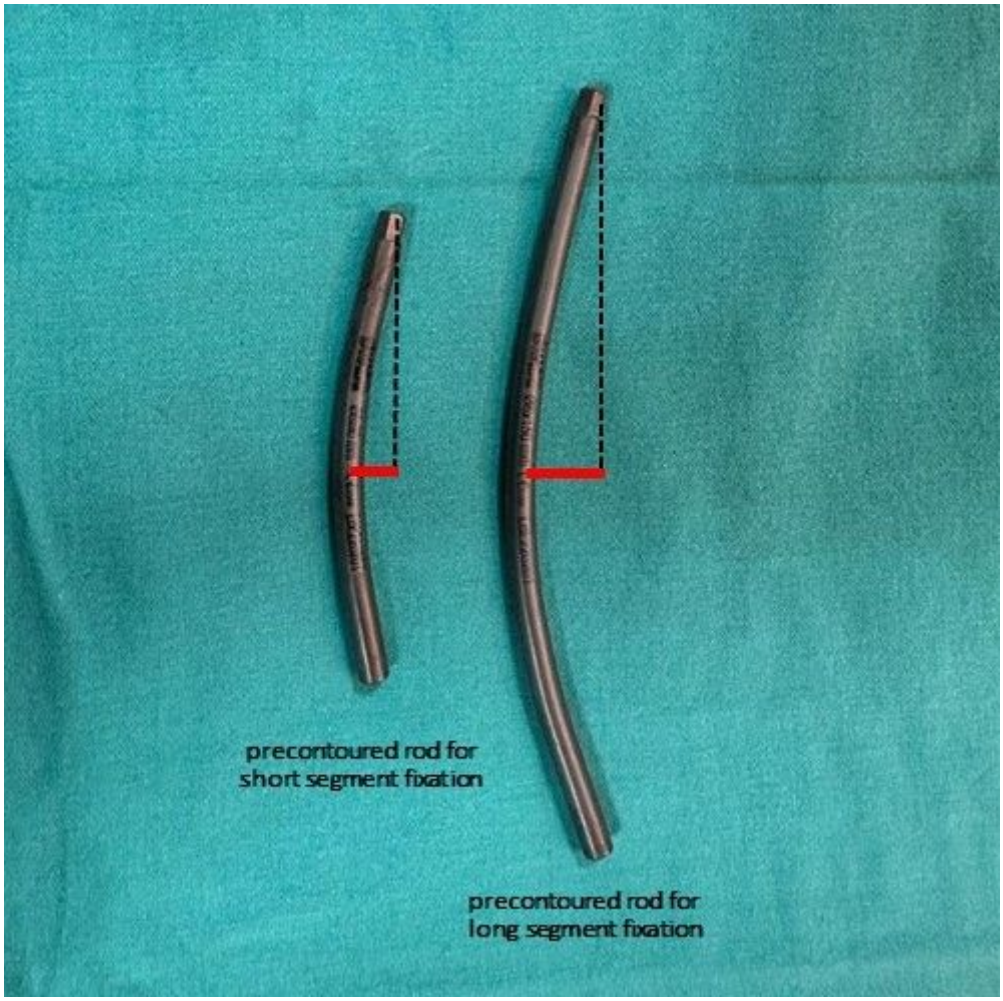


Figure 3

Precontoured rods.

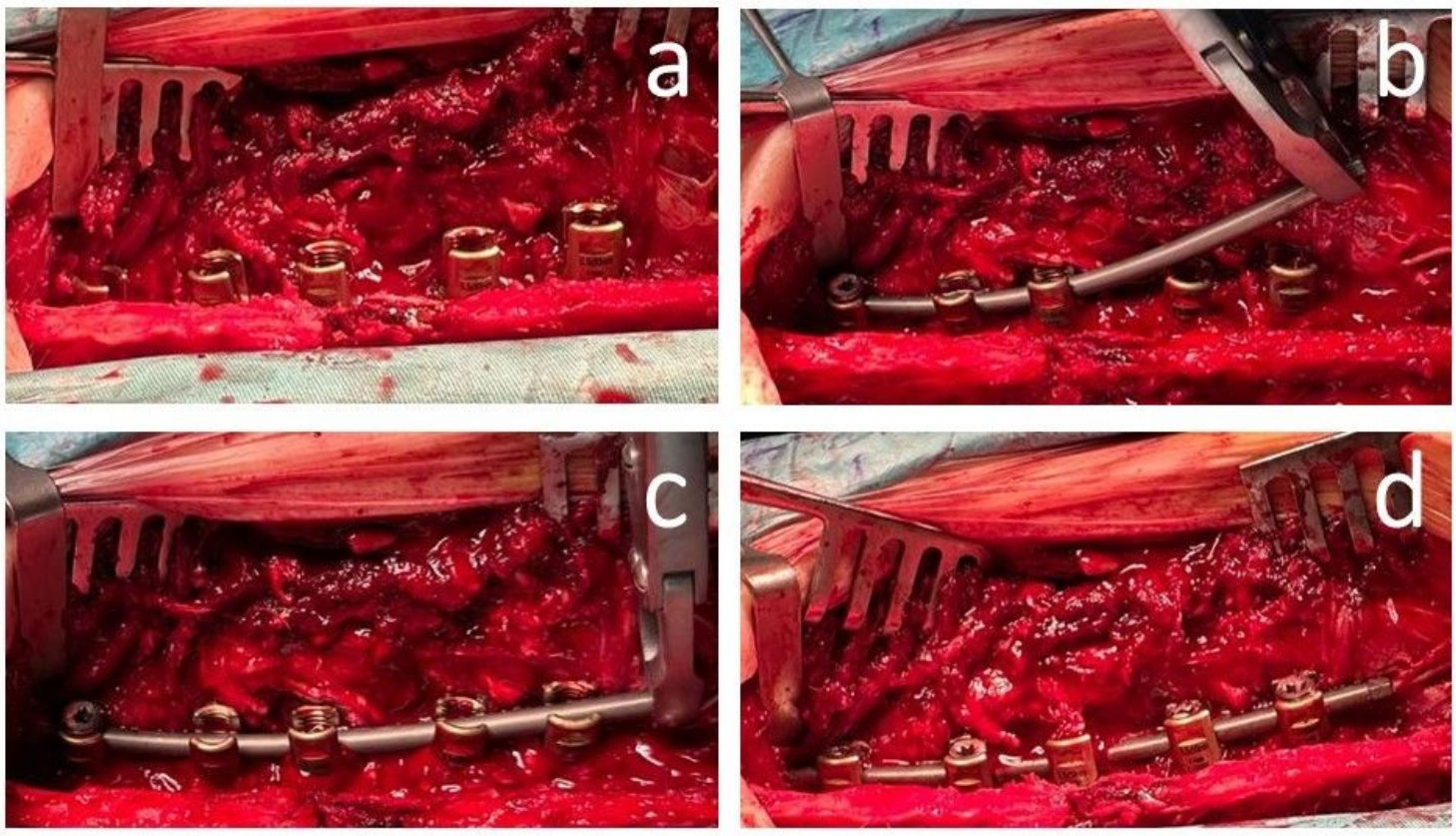


Figure 4

Using a longer precountered rod during surgery may help more in achieving correction of the kyphosis during surgery.

Supplementary Files

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