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RESEARCH

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Unique characteristics of bone union at the infected vertebrae after minimally invasive posterior fixation without bone grafting in thoracolumbar pyogenic spondylitis: a retrospective multicenter cohort study

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Abstract

Background The current study aimed to evaluate the bone union rate between infected vertebrae after minimally invasive posterior fixation without bone grafting in thoracolumbar pyogenic spondylitis.

Methods This retrospective multicenter cohort study evaluated 75 patients of posterior fixation for thoracolumbar pyogenic spondylitis that have been recorded at six relevant institutions from January 2016 to December 2022. Data on age, sex, location of infected vertebrae, number of infected disks, comorbidity, Pola classification, number of vertebrae fixed according to surgery, implant failure requiring revision surgery, and distance according to the type of infected vertebrae after surgery were evaluated. Further, their association with postoperative bone union was investigated > 12 months postoperatively.

Results Finally, 40 patients were included in the study. In total, 32 (80%) patients achieved bone union at the infected vertebrae after minimally invasive posterior fixation without bone grafting. The mean duration from surgery to union was 10.7 months. Twenty-six (65%) patients initially achieved bone union at the lateral and/or anterior bridging callus. Patients with multiple-level infected disks (33%, 2/6 patients) had a lower bone union rate than those with a single-level infected disk (88%, 30/34 patients) ($p = 0.0095$).

Conclusions In 80% of patients, bone union at the infected vertebrae was achieved after minimally invasive posterior fixation without bone grafting in thoracolumbar pyogenic spondylitis. A total of 65% of the patients achieved initial bone union at the lateral and/or anterior bridging callus. Moreover, patients with multiple-level infected disks had a low bone union rate. Hence, the treatment strategy should be cautiously considered.

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Trial registration This study was registered retrospectively and all procedures used in this study including the review of patient records were approved by the institutional review board.

Keywords Pyogenic spondylitis, Posterior fixation, Minimally invasive spine surgery, Bone union

Background

The surgical treatment for pyogenic spondylitis has evolved in recent years from traditional anterior debridement and autogenous bone grafting to percutaneous endoscopic debridement, minimally invasive anterior and posterior surgery, and combination therapy [1–5].

Minimally invasive posterior fixation without debridement of the infected vertebrae, mainly with percutaneous pedicle screws (PPSs), has been found to be effective, thereby providing pain relief and facilitating infection control via local stabilization [6–9].

In general, nonunion between vertebrae is one of the common complications causing implant failure in spine surgery [10, 11].

Bone union at the infected vertebrae after treatment in pyogenic spondylitis is an indicator of long-term quiescence of infection. However, there are only few studies on characteristics of bone union in posterior fixation without bone grafting [6, 12–15]. The need for anterior surgery based on bone defect size and the efficacy of posterior fixation alone are controversial. Further, the rate of bony union with posterior fixation alone is not yet clear [3, 16].

The current study aimed to evaluate the rate of bone union between infected vertebrae after minimally invasive posterior fixation without bone grafting in thoracolumbar pyogenic spondylitis. Further, the factors affecting bone union were investigated.

Methods

This was a multicenter, retrospective cohort study, and the study methodology was approved by the authors' affiliated institutional review board. The patients and/or their families were informed that data from the research would be submitted for publication, and gave their consent.

In total, 75 patients of posterior fixation for thoracolumbar pyogenic spondylitis that have been recorded at six relevant institutions recorded from January 2016 to December 2022 were evaluated.

Inclusion criteria were as follows:

1. Thoracolumbar pyogenic spondylitis (T1/2–L5/S1) patients treated with posterior fixation only, without anterior or posterior infected disk debridement or bone grafting; patients treated with minimally invasive spine surgery, mainly PPS.
2. A postoperative follow-up period of at least 12 months.

Exclusion criteria were as follows: patients with short follow-up (< 12 months postoperatively).

Data on the following items were evaluated:

1. Demographic and clinical characteristics of the patients: sex, age, location of infected vertebrae (thoracic and thoracolumbar (T1/2–T12/L1), lumbar and lumbosacral (L1/2–L5/S1)), number of infected disks, comorbidity, extravertebral abscess, Pola classification [17], and causative organisms.
2. Surgery-related items: number of vertebrae fixed according to surgery, and distance between the infected vertebrae after surgery.
3. Postoperative items: postoperative follow-up period, duration of postoperative antibiotics, implant failure requiring revision surgery, recurrent infection, presence and location of postoperative bone union, duration from surgery to bone union, and implant removal.

Pola classification [17] classified patients into the following three categories based on preoperative imaging and neurological symptoms; Type A: no bone destruction, segmental instability, epidural abscess, or neurological impairment; Type B: no epidural abscess or neurological impairment, but with bone destruction or segmental instability; Type C: with epidural abscess or neurological impairment.

Number of vertebrae fixed according to surgery was two to three levels above and below the infected vertebrae, considering age and bone quality [6, 9]. The final decision on number of vertebrae fixed according to surgery and whether to insert the PPS into the infected vertebrae was made by the surgeon at each institution.

Radiological evaluation

The distance between the infected vertebrae after surgery was assessed via postoperative computed tomography (CT) scan. The coronal plane was reconstructed at the center of the vertebral body, and the average distance between the right and left endplates was evaluated (Fig. 1).

Bone union was determined on postoperative CT scan and was defined as the presence of bony continuity between the superior and inferior vertebral bodies at the sagittal or coronal plane. If bone union was achieved, the sites of initial bone union (anterior bridging callus, posterior bridging callus, lateral bridging callus, and extra

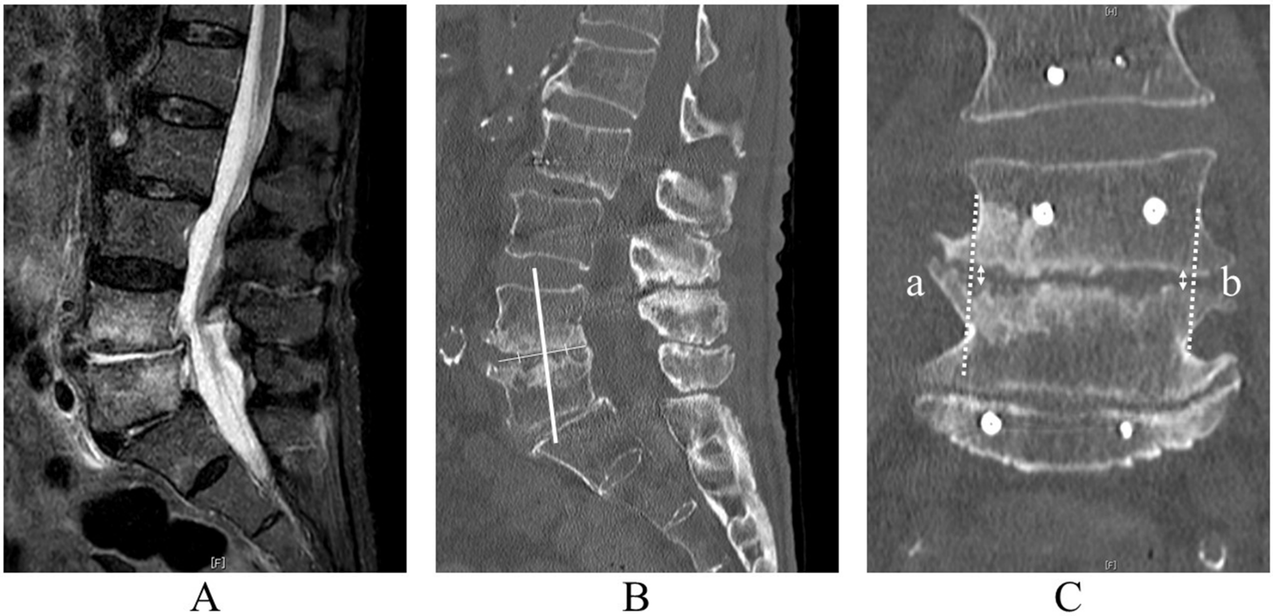


Fig. 1 Method for measuring the distance between the infected vertebrae after surgery. A case of pyogenic spondylitis at L4/5 was shown (**A**, magnetic resonance imaging). The coronal plane of postoperative computed tomography was reconstructed at the center of the vertebral body (**B**, solid line). The mean distance between right and left endplates (**C**, a and b) at the outer edge of the infected vertebral body (dotted line) was measured

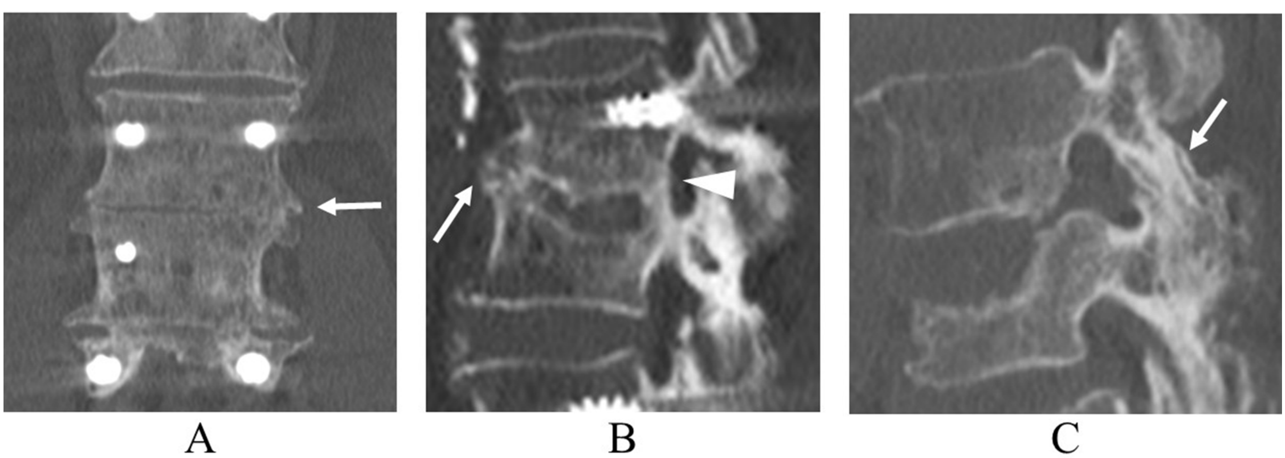


Fig. 2 Locations where initial bone union was achieved. Postoperative computed tomography scan evaluated the bone union locations: lateral bridging callus (**A** arrow), anterior bridging callus (**B** arrow), posterior bridging callus (**B** arrowhead), and extra body (spontaneous facet joint union: **C** arrow)

body [spontaneous facet joint union]) were evaluated (Fig. 2).

Statistical analysis

Based on previous reports, we evaluated age, sex, location of the infected vertebrae (thoracic and thoracolumbar, lumbar and lumbosacral), number of infected disks, comorbidity, Pola classification, number of vertebrae fixed according to surgery, implant failure requiring revision surgery, and distance between the infected vertebrae after surgery. Moreover, their association with postoperative bone union was assessed [18].

Age, number of vertebrae fixed according to surgery, and distance between the infected vertebrae after surgery were considered as continuous variables and sex, location of the infected vertebrae, number of infected disks, comorbidity, Pola classification, and implant failure requiring revision surgery as nominal variables. The Welch's t-test was used to evaluate continuous variables, and the Fisher's exact test was utilized to investigate nominal variables. A p value of < 0.05 was considered statistically significant. The JMP 10 software (SAS Inc., Cary, NC, the USA) was used in all analyses.

Table 1 Demographic and clinical characteristics of the patients

	Total (*n* = 40)	Range
Sex		
Male	26 (65%)	
Female	14 (35%)	
Age (years)	72.8 ± 10.2	47–88
Location of the infected vertebrae		
Lumbar and lumbosacral (L1/2–L5/S1)	25 (62.5%)	
Thoracic and thoracolumbar (T1/2–T12/L1)	15 (37.5%)	
Number of infected disks		
1	34 (85%)	
2	6 (15%)	
Comorbidity		
With comorbidities (including duplicated)	26 (65%)	
Diabetes mellitus	11 (28%)	
Cancer	6 (15%)	
Abdominal infection	4 (10%)	
Daily steroid use	3 (8%)	
Others	7 (18%)	
Extravertebral abscess (including duplicated)	28 (70%)	
Epidural abscess	24 (60%)	
Iliopsoas abscess	16 (40%)	
Pola classification		
Type A	4 (10%)	
Type B	9 (22.5%)	
Type C	27 (67.5%)	
Postoperative follow-up period (months)	29.0 ± 14.0	12–71
Duration of postoperative antibiotics (months)	6.4 ± 7.3	0–28
Number of vertebrae fixed according to surgery	6.4 ± 1.4	4–10
Implant failure requiring revision surgery	3 (8%)	

Values are in mean ± standard deviation

Table 2 Causative organisms

Organism	n
Specified	29
GPC without anaerobic bacteria (%)	17 (58.6%)
Streptococcus species	10
MSSA	5
CNS	1
MRSA	1
GNR without anaerobic bacteria	8 (27.6%)
Escherichia coli	5
Klebsiella pneumoniae	3
Anaerobic bacteria	4 (13.8%)
Bacteroides fragilis	1
Gemella haemolysans	1
Parvimonas micra	1
Peptostreptococcus micros	1
Not specified	11

GPC: Gram-positive cocci, MSSA: Methicillin-susceptible *Staphylococcus aureus*, CNS: Coagulase-negative *staphylococci*, MRSA: Methicillin-resistant *Staphylococcus aureus*, GNR: Gram-negative rod

Table 3 Bone union of the infected vertebrae

	n	Range
Total	40	
Bone union	32 (80%)	
Duration from surgery to bone union (months)	10.7 ± 5.8	2–33
Locations where initial bone union was achieved (including duplicated) (*n* = 32)		
Lateral bridging callus	19 (59%)	
Anterior bridging callus	7 (18%)	
Posterior bridging callus	4 (13%)	
Whole vertebrae	3 (9%)	
Extra body (spontaneous facet joint union)	2 (6%)	

Values are in mean ± standard deviation

Results

Finally, 40 patients were included in the study. Thirty-five patients with insufficient follow-up due to dropouts were excluded. The mean age of the patients was 72.8 (range: 47–88, standard deviation [SD]: 10.2) years. In total, there were 26 male and 14 female patients (Table 1).

The locations of the infected vertebrae were as follows: thoracic and thoracolumbar, $n = 15$, lumbar and lumbosacral, $n = 25$. Moreover, 34 patients presented with 1 infected disk and 6 with two infected disks. Twenty-six patients had comorbidities, and 28 patients had extravertebral abscesses. Pola classification was type A in 4 patients, type B in 9 patients, and type C in 27 patients. The mean postoperative follow-up period was 29.0 (range: 12–71, SD: 14.0) months. The mean number of vertebrae fixed via surgery was 6.4, with most fixations being 3 above and 3 below, with an infected disk in between. Three patients presented with implant failure requiring revision surgery. All patients underwent extended posterior fixation for screw backout and loosening. The specified rate of the causative organism was 73% (29/40 patients), with Gram-positive cocci (GPC) and *Streptococcus* species being common (Table 2).

Bone union of the infected vertebrae

In total, 32 (80%) patients achieved bone union at the infected vertebrae after minimally invasive posterior fixation without bone grafting (Table 3). The duration from surgery to union was 10.7 (range: 2–33, SD: 5.8) months. The locations where the initial bone union was achieved (which included duplications) were as follows: 19 patients in the lateral bridging callus, 7 in the anterior bridging callus, 4 in the posterior bridging callus, 3 in the whole vertebrae, and 2 in the extra body (spontaneous facet joint union). None of the patients had bone union from the center of the vertebral body (i.e., the disk). In several patients, bone union was initially achieved at either the lateral or anterior bridging callus (Figs. 3 and 4). During the follow-up period, implant removal was performed in 14 patients. All of these were patients in whom bone union was achieved.

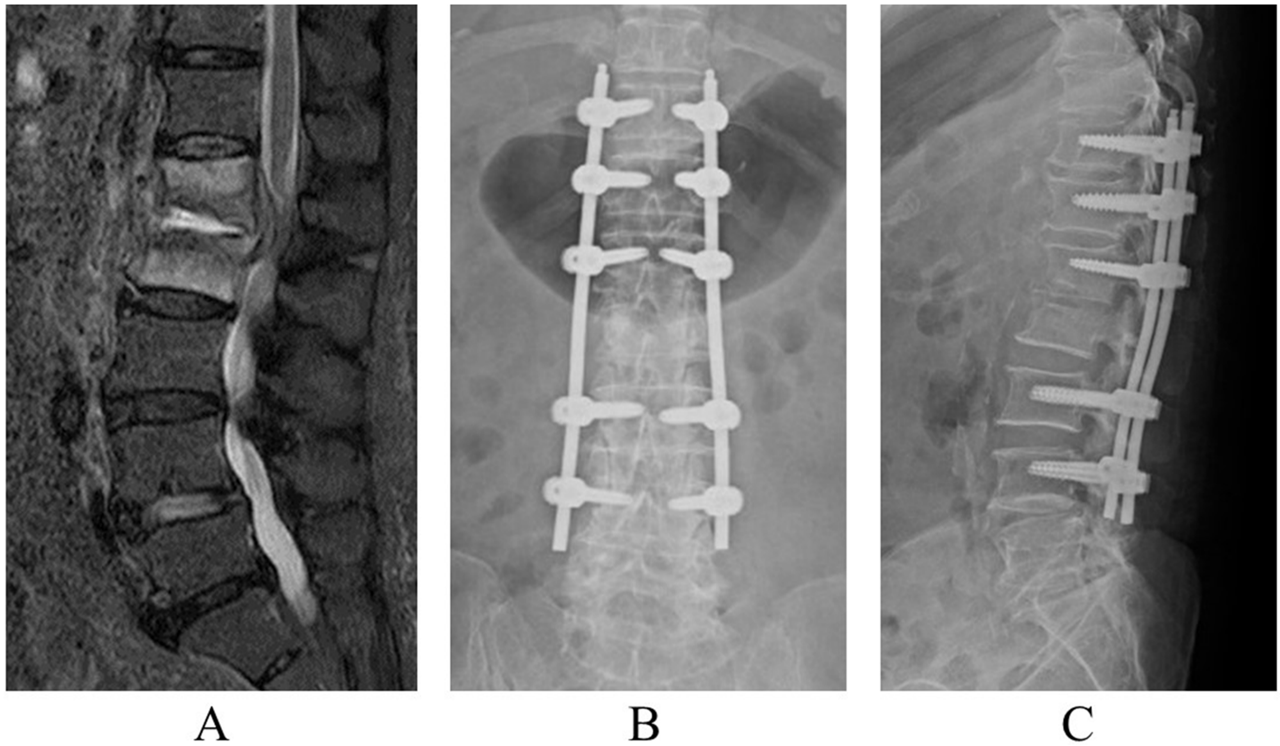
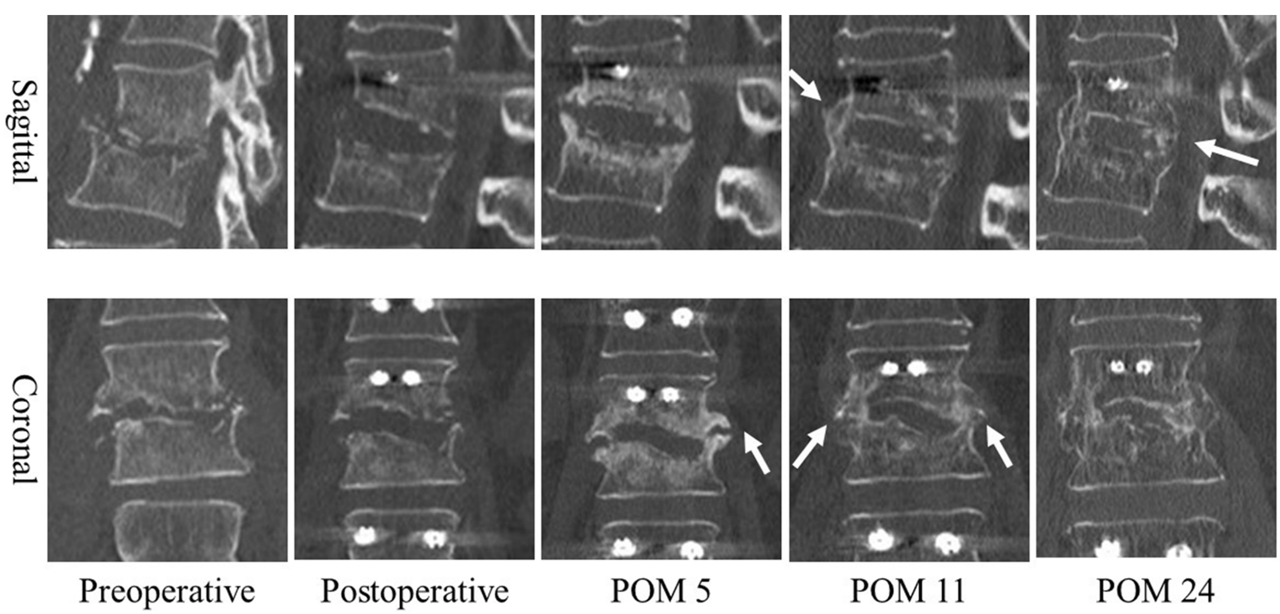


Fig. 3 Illustrative case of bone union. An 83-year-old woman with single-level pyogenic spondylitis at L1/2 (**A**) underwent posterior fixation alone (**B**, **C**)



Figs. 4 Progression of bone union on computed tomography scan in an illustrative case of bone union. Preoperatively, significant endplate destruction. Lateral callus generally united (arrow) at 5 months, anterior and bilateral callus united (arrows) at 11 months, and posterior callus united (arrow) at 24 months postoperatively. POM: Postoperative month

Factors associated with bone union

The factors associated with bone union between the union group ($n=32$) and the nonunion group ($n=8$) were compared (Table 4). No recurrent infection was observed.

In terms of the number of infected disks, patients with multiple-level infected disks (33%, 2/6 patients) had a lower bone union rate than those with a single-level infected disk (88%, 30/34 patients) ($p=0.0095$) (Fig. 5).

Table 4 Factors associated with bone union

Factors	Union	Nonunion	P value
Total (n=40)	32 (80%)	8 (20%)	
Sex			
Male (n=26)	20 (77%)	6 (23%)	0.69a
Female (n=14)	12 (86%)	2 (14%)	
Age (years)	72.3±11.1	74.3±5.8	0.51b
Comorbidity			
With (n=26)	19 (73%)	7 (27%)	0.22a
Without (n=14)	13 (93%)	1 (7%)	
Location of infected vertebrae			
Lumbar and lumbosacral (L1/2–L5/S1) (n=25)	20 (80%)	5 (20%)	1.00a
Thoracic and thoracolumbar (T1/2–T12/L1) (n=15)	12 (80%)	3 (20%)	
Number of infected disks			
1 (n=34)	30 (88%)	4 (12%)	0.0095a
2 (n=6)	2 (33%)	4 (67%)	
Pola Classification			0.85a
Type A (n=4)	4 (100%)	0 (0%)	
Type B (n=9)	7 (78%)	2 (22%)	
Type C (n=27)	21 (78%)	6 (22%)	
Number of vertebrae fixed according to surgery	6.4±1.4	6.3±1.6	0.80b
Implant failure requiring revision surgery			
With (n=3)	1 (33%)	2 (67%)	0.096a
Without (n=37)	31 (84%)	6 (16%)	
Distance between the infected vertebrae after surgery (mm, range)	5.2±2.8 (1.60–13.8)	8.3±5.1 (1.55–21.0)	0.073b

a: Fisher's exact test, b: Welch's *t*-test, Values are in mean±standard deviation

The overall mean distance between the infected vertebrae after surgery was 6.0 (range: 1.55–21) mm. The mean distances between the infected vertebrae after surgery were 5.2 (1.60–13.8) mm in the union group and 8.3 (1.55–21) mm in the nonunion group. There was no significant difference between the union and nonunion groups in terms of the mean distance between the infected vertebrae (p=0.073). Bone union was achieved from the lateral and anterior bridging callus even in a case with a maximum distance of 13.8 mm.

Discussion

When evaluated>12 months postoperatively, the bone union rate of the infected vertebrae after minimally invasive posterior fixation was 80%. Bone union was achieved at an average of 10.7 months postoperatively, and 65% of the patients had union at the anterior and/or lateral bridging callus. To the best of our knowledge, this study is the first to reveal the detailed characteristics of bone union after minimally invasive posterior fixation without bone grafting in thoracolumbar pyogenic spondylitis.

In recent years, minimally invasive posterior fixation for pyogenic spondylitis along with percutaneous endoscopic debridement and minimally invasive anterior and posterior surgery has undergone several developments [3–9].

On the contrary, the rate of bone union at the site of infection, which is an indicator of infection control and stable long-term outcomes, after posterior fixation without bone graft is 50–86% [6, 12, 13, 15].

The mechanism by which infected vertebrae can achieve bone union with posterior fixation alone without bone grafting, is still unclear. In relation to this, there are only a few reports on the rate of bone union with minimally invasive posterior fixation and the timing and morphology of bone union.

In the current study, patients with two infected disks had a low bone union rate. Previous studies have reported no difference in the rate of bone union between single- and multiple-level infected disks [18]. By contrast, there are reports showing that anterior debridement and autogenous bone grafting is important if there is a large bone defect in the vertebral body [3, 19]. Hence, the treatment strategy should be cautiously considered in patients with multiple-level infected disks [3, 18, 19].

In this study, the overall bone union rate was 80%, which was comparable with that of previous reports using cages or bone grafts [3, 6, 12, 13, 15, 18]. The average number of vertebrae fixed surgically in this study was 6.4. Notably, a sufficient range of fixation (at approximately 3 above and 3 below) results in a sufficient percentage of bony union with posterior fixation alone.

The need for anterior debridement and autogenous bone grafting for a specific size of bone defect in the vertebral body remains controversial. However, in the current study, there was no difference in the presence of bone union and the distance between the infected vertebrae [3, 16, 19]. For a defect measuring approximately within 10 mm, bone union can be achieved without anterior debridement and autogenous bone grafting, even with posterior fixation alone.

Anterior union with debridement and autologous bone grafts or cages is a good approach. However, there are concerns about complications specific to iliac bone harvesting or anterior surgery [20–23].

Posterior fixation alone is advantageous as it is safe and minimally invasive. Hence, it can be used for the treatment of pyogenic spondylitis, which is commonly observed in elderly patients, as in this study.

The bone union rate in this study was 80%, with most patients achieving initial bone union anteriorly or laterally in the vertebral body. It is challenging to achieve bone union via posterior fixation alone in the normally avascular disk and intervertebral spaces, and a bony

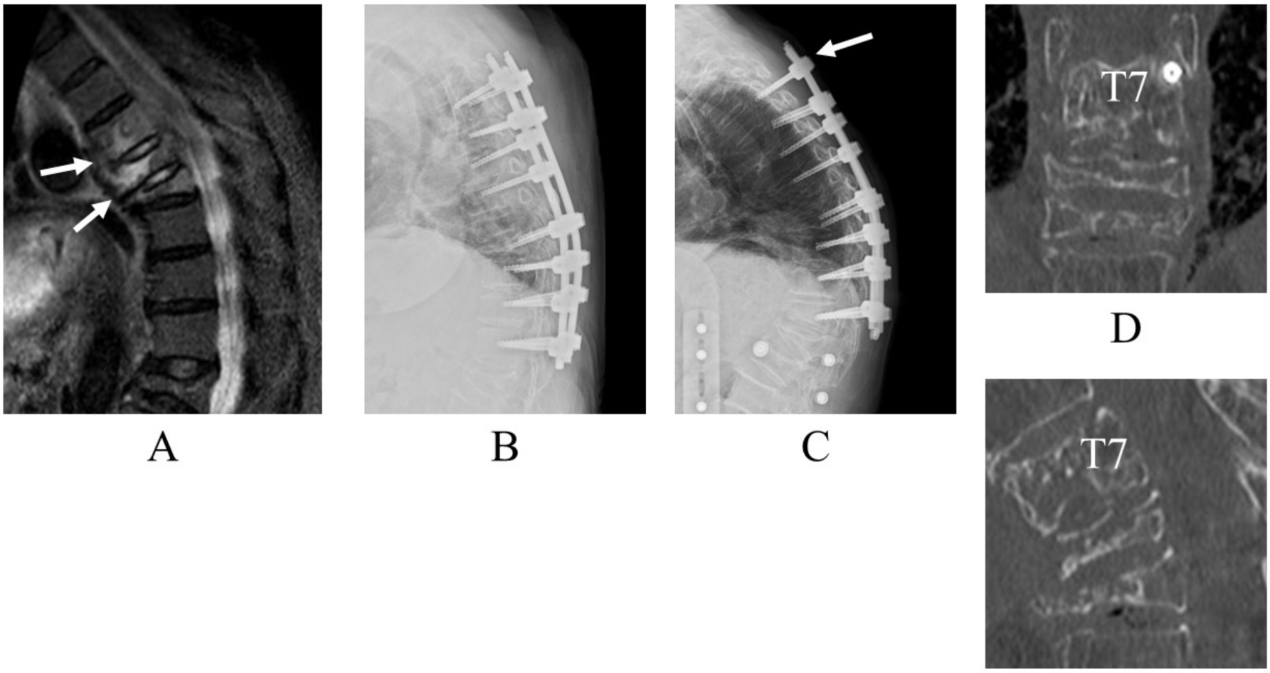


Fig. 5 Illustrative case of nonunion. 83-year-old woman with T7/8 and T8/9 pyogenic spondylitis (**A**: arrows) underwent posterior fixation (**B**). Postoperatively, proximal pedicle screws backed out (**C**: arrow). At 21 months postoperatively, T8 showed pseudarthrosis without bone union (**D**, **E**)

bridge was formed outside the vertebral body, as is often the case with lateral interbody fusion [24, 25].

Based on the distribution of blood flow in the vertebral body, the anterior and lateral areas of the vertebral body, where there is good blood flow due to the surrounding arteries, are a favorable environment for bone union. Moreover, local stabilization via posterior fixation facilitates bone union [26].

This study had several limitations. First, it was retrospective in nature. Further, it was conducted at multiple centers and had an acceptable 1-year follow-up for infections. However, whether the results of this study can be applied to all patients is unclear.

Regarding patient selection bias, the dropout rate in this study was relatively high at 47%, which may impact the overall results. Despite our efforts to maintain a high follow-up rate, the significant dropout rate may be attributed to the fact that our patients were elderly, with a mean age of 72.8 years and a high prevalence of comorbid conditions (65%). The results were derived from a population with high comorbidity, and caution should be exercised when applying these findings to other geographic areas.

In patients who achieved bone union, the maximum distance between the infected vertebrae after posterior fixation was only approximately 13.8 mm. This study could not conclude how large a bone defect can be achieved bone union with posterior fixation alone.

In this study, patients with multiple-level infected disks had inferior bone union rates. However, there were only six of them. Although the difference was statistically significant, more patients are required to make a definitive conclusion.

Another limitation of the study is the variation in the distribution of causative organisms. In this study, as in previous research, GPC were the most frequently detected, followed by Gram-negative rods and anaerobic bacteria [27]. While Methicillin-susceptible *Staphylococcus aureus* is generally the most common organism in pyogenic spondylitis, our study found that *Streptococcus species* were the most prevalent. Recent reports indicate that the prevalence of oral commensal organisms, particularly Streptococcus spp., is increasing in our region [28]. Therefore, the distribution of causative organisms in our study may reflect a changing trend specific to our country. Caution is needed when applying these results to regions with different organism distributions.

The mean number of vertebrae fixed according to surgery did not differ between the two groups, but the minimum was 4 vertebrae and the maximum was 10 vertebrae, which was determined at the discretion of each institution and varied. The variation in the number of vertebrae fixed according to surgery may have influenced postoperative bone union and implant failure, which is a limitation of this study.

Also, in the region where this study was conducted, the augmented screw for PPS became available in November 2022. The lack of patients with augmented screws, which generally reduce complications such as implant failure in the elderly, and the potential for improved clinical outcomes with the use of augmented screws are features and limitations of the study region [29, 30].

Nevertheless, the current study had several strengths. That is, it was performed at six institutions, from university hospitals to tertiary emergency centers and regional hospitals. Thus, the results could be generalizable. However, this research was conducted at a monoethnic developed country. The participants had a mean age of 72.8 years, and a large number of elderly patients were included. Hence, caution should be observed in regions with different age groups.

Conclusions

The rate of bone union at the infected vertebrae after minimally invasive posterior fixation without bone grafting in thoracolumbar pyogenic spondylitis was 80% when investigated > 12 months postoperatively, and the mean duration from surgery to bone union was 10.7 months. A total of 65% of the patients achieved initial bone union at the lateral and/or anterior bridging callus. Patients with multiple-level infected disks had a low bone union rate. Thus, the treatment strategies should be cautiously considered.

Abbreviations

PPS	Percutaneous Pedicle Screw
CT	Computed Tomography
GPC	Gram-positive cocci
SD	Standard Deviation

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Not applicable.

Author contributions

HG, TF and MK conceived and designed the study. HG, KN, TN, SO, KO, YS, KN, KF, YT, MT, IS and TN gathered and analyzed the data for the study. HG, TF, and MK drafted the paper. MY and MK significantly revised the drafted the manuscript. All the authors approved the version of the manuscript submitted for publication.

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Data availability

The datasets generated during and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

All procedures, including the review of patient records used in this research, were approved by the institutional review board (IRB) of Ibaraki Western Medical Center (protocol code No. 21 – 07, approved on 27 January 2022). All procedures were performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients who participated in this study. The IRB approved the procedures outlined for obtaining consent for this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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