Surgical strategy of lumbopelvic instrumentation in the treatment of lumbosacral tuberculosis: S2-alar-iliac screws vs iliac screws

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Abstract
The objective of this study was to evaluate the feasibility and clinical outcomes of S2-alar-iliac (S2AI) and iliac screw (IS) techniques in the lumbopelvic reconstruction of lumbosacral tuberculosis patients. From January 2014 to August 2016, 26 patients with lumbosacral tuberculosis attending the 8th Medical Centre of Chinese PLA General Hospital were included in this retrospective study. The subjects were divided into two groups based on the lumbopelvic fixation type (16 patients in the S2AI group, 10 patients in the IS group). The operation time, blood loss, length of hospitalisation, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) level, visual analogue scale (VAS), Oswestry Disability Index (ODI), ambulatory status, and 36-Item Short-Form Health Survey (SF-36) scores of the patients in two groups were recorded and compared. In addition, surgical complications were collected and analysed. The operation time and intraoperative blood loss were significantly lower in the S2AI group than that in the IS group (P < .05). Compared with preoperative data, postoperative data showed significant improvement in ESR, CRP level, visual analogue scale (VAS), Oswestry Disability Index (ODI), ambulatory status, and 36-Item Short-Form Health Survey (SF-36) scores of the patients in two groups were recorded and compared. In addition, surgical complications were collected and analysed. The operation time and intraoperative blood loss were significantly lower in the S2AI group than that in the IS group (P < .05). Compared with preoperative data, postoperative data showed significant improvement in ESR, CRP level, ODI scores, VAS scores, ambulatory status, and SF-36 (P < .05), but there was no significant difference in remission degree between the two groups. Compared with IS group, The S2AI group had significantly lower rates of symptomatic screw prominence (P < .05). Both the IS and S2AI fixation techniques can achieve satisfactory outcomes for the restoration of lumbosacral stability of lumbosacral tuberculosis. Furthermore, compared to the traditional IS fixation technique, the S2AI fixation technique can shorten operation time and reduce surgical trauma for the treatment of lumbosacral tuberculosis.

Abbreviations: CRP, C-reactive protein; CT, computed tomography; ESR, erythrocyte sedimentation rate; IS, iliac screw; ODI, Oswestry Disability Index; S2AI, S2-alar-iliac; SF-36, 36-Item Short-Form Health Survey; VAS, visual analogue scale.
Spinal tuberculosis is one of the most common forms of extrapulmonary tuberculosis, accounting for approximately 50% of all osteoarticular tuberculosis cases. It affects mainly the weight-bearing vertebrae and has aggressive behaviours.\textsuperscript{1} Although lumbosacral tuberculosis accounts for only 2% to 3% of spinal tuberculosis cases, its unique anatomical and biomechanical characteristics present specific treatment challenges.\textsuperscript{2} Surgery is indicated for lumbosacral tuberculosis patients with severe complications; however, the optimal surgical strategy is controversial.\textsuperscript{3-7} The anterior-only approach allows direct access to the focus and is convenient for debridement and restoration of stability. However, it has increased risks of iliac vessel injury and retrograde ejaculation.\textsuperscript{4} Combined anterior and posterior procedures can achieve thorough debridement, high rates of bone fusion, and effective deformity correction. However, they are associated with increased surgical trauma and morbidity.\textsuperscript{5} The posterior-only approach provides circumferential decompression and stronger three-column fixation via pedicle screws simultaneously, which has gained increased popularity in recent years.\textsuperscript{6,7}

The sacrum is the keystone of pelvic ring. For lumbosacral tuberculosis patients with severe destruction of L5 and S1 vertebrae, how to select the optimal internal fixation in posterior-only procedures to achieve effective and stable recovery remains challenging. It is difficult to achieve tricortical purchase with traditional S1 pedicle screw fixation, and this technique has poor mechanical properties.\textsuperscript{8-10} Iliac screw (IS) fixation is an effective technique for lumbopelvic fixation. However, drawbacks to the IS technique include extensive soft tissue dissection, symptomatic screw prominence, and the requirement of offset connector use.\textsuperscript{11,12} To overcome such disadvantages, the S2-alar-iliac (S2AI) screw technique was developed to achieve enhanced mechanical properties with less dissection, a lower profile, and ease of assembly.\textsuperscript{13,14} In our hospital, the traditional IS and S2AI techniques used for the management of lumbosacral tuberculosis have evolved over time. However, reports on the clinical efficacy of S2AI and IS techniques for the treatment of lumbosacral tuberculosis are scarce in the literature.

The objective of this study was to evaluate the feasibility and clinical outcomes of S2AI and IS techniques in the lumbopelvic reconstruction of lumbosacral tuberculosis patients, further to compare the surgical trauma, radiographic and functional outcomes, rates of implant failure and pseudarthrosis, sacroiliac joint pain, and symptomatic screw prominence between two techniques, which may provide a basis for improving the clinical treatment.

\section*{METHODS}

\subsection*{Patient population}

From January 2014 to August 26, 2016, patients with lumbosacral tuberculosis attending the 8th Medical Centre of Chinese PLA General Hospital were included in this retrospective study. The subjects were divided into two groups based on the lumbopelvic fixation type (16 patients in the S2AI group and 10 patients in the IS group) (Figure 1). ISs were preferentially utilised during the period from January 2014 to March 2015, and S2AI screws were favoured from April 2015 to August 2016. This study protocol was formulated in accordance with the requirements of the Declaration of Helsinki of the World Medical Association. It was approved by the Ethics
Committee of the 8th Medical Centre of Chinese PLA General Hospital (NO. 309201909231003).

### 2.2 Inclusion and exclusion criteria

Inclusion criteria: (a) severe destruction of the S1 vertebra without sufficient space for S1 pedicle screw implantation; (b) patients underwent debridement, bone grafting, and lumbopelvic fixation (S2AI or IS); and (c) a follow-up period ≥18 months.

Exclusion criteria: (a) patients with a history of lumbosacral surgery; (b) patients lost to follow-up were excluded.

### 2.3 Surgical procedures

All the included patients underwent surgery by the same spine specialist with 15 years of experience. All patients in both groups received transpedicular debridement, autologous tri-crest iliac bone grafting, and instrumentation via the posterior-only approach. The S2AI technique has been reported by Kebaish et al. The starting point was located lateral to the midpoint between the S1 and S2 dorsal foramen and should be in line with the proximal S1 anchors. A small sharp awl was used to mark the entry point. Then, a 3.2-mm blunt-tipped pedicle probe was used with a lateral (approximately 40° to the horizontal plane) and 20° to 30° caudal (depending on the pelvic tilting) trajectory. When the cortical surface of the sacroiliac joint was reached, the pedicle probe was removed, and 5 bony borders (medial, lateral, superior, inferior, and bottom) were confirmed by a ball-tip probe. The cortical wall of the sacroiliac joint was penetrated by cautiously hammering the blunt-tipped pedicle probe. A teardrop C-arm view at this step helped ensure the anteroposterior trajectory without cortical breach within the thickest part of the ilium (Figure 2).

IS placement was performed using a rongeur to remove the part of the iliac crest of the posterior superior iliac spine. ISs were implanted in the direction from the posterior superior iliac spine to the anterior inferior iliac spine (Figure 3). The diameters of the S2AI screws and ISs used in this study were both 7.5 mm, and the lengths were 65 to 80 mm according to the anatomical characteristics of the Chinese population.

### 2.4 Postoperative management

The standard chemotherapy regimen of rifampicin/isoniazid/ethambutol/pyrazinamide was administered for 3 months. Then, a regimen of rifampicin/isoniazid/ethambutol was continued for 9 to 15 months. If drug-susceptibility testing indicated drug-resistant Mycobacterium tuberculosis, individualised chemotherapy was tailored for these patients based on their previous chemotherapy history and drug-susceptibility profiles.
2.5 Evaluation of clinical outcomes

The operation time, blood loss, and length of hospitalisation were compared between the two groups. The visual analogue scale (VAS), Oswestry Disability Index (ODI), and 36-Item Short-Form Health Survey (SF-36) scores of the patients in two groups were also recorded and compared preoperatively, at 1 week postoperatively and at the final follow-up. Fusion, complications, such as sinus formation, pseudarthrosis, implant failure, sacroiliac joint pain, and symptomatic device prominence were also recorded to compare between the two groups.

2.6 Statistical analysis

All the data collected in this study were analysed using SPSS 19.0 software. The normality of continuous variables was tested by the Shapiro-Wilk test as well as the graphical illustration of histograms and Q-Q plots. Normally distributed measurement data were expressed as mean ± SD, while non-normally distributed measurement data were expressed as median (interquartile range), and the comparisons were examined by Student $t$-test and Mann-Whitney test (non-parametric distribution). The categorical data were expressed as n (%), and the differences between the two groups were examined by chi-square analysis or Fisher’s Exact Test. The statistical significance level was set at 0.05 for a two-sided test.

3 RESULTS

3.1 Demographics and clinical characteristics

Twenty-six patients with lumbosacral tuberculosis meeting the eligibility criteria were enrolled in this study.
IS fixation in a 45-year-old female patient with lumbosacral tuberculosis (L5-S1). A,B, Posteroanterior and lateral radiographs before the surgical intervention respectively. C, Preoperative sagittal reconstruction image of computed tomography (CT). D, Preoperative sagittal STIR image of MRI. E, Preoperative axial T2 image of MRI, which shows local bone destruction of L5 to S1 and the formation of intraspinal and presacral abscess. F,G, Posteroanterior and lateral radiographs 7 days after the surgery of posterior debridement with bone graft fusion and internal fixation (IS). H, CT sagittal reconstruction of lumbosacral spine 7 days postoperatively, showing good position of the autologous tri-crest iliac bone. I,J Posteroanterior and lateral anterior images of the postoperative follow-up for two and a half years, respectively, suggesting good bone fusion. MRI, magnetic resonance imaging; STIR, short T1 inversion recovery.

| Baseline characteristics | S2AI (n = 16) | IS (n = 10) | P-value |
|--------------------------|--------------|-------------|---------|
| Age (±s, y)              | 51.2 ± 18.3  | 53.6 ± 15.8 | .727    |
| Sex (male/female, cases) | 9/7          | 6/4         | .826    |
| Osteoporosis or osteopenia (cases) | 2          | 1          | .662    |
| Follow-up period (±s, mo) | 23.7 ± 3.9  | 24.1 ± 4.3  | .809    |
| Fixed segment [cases (%)] |             |             |         |
| L3-S2 (I)                | 3 (18.6)     | 1 (10)      | .966    |
| L4-S2 (I)                | 8 (50)       | 6 (60)      | .926    |
| L5-S2 (I)                | 5 (31.3)     | 3 (30)      | .712    |
| Preoperative symptoms [cases (%)] |             |             |         |
| Mechanical pain          | 14 (87.5)    | 9 (90)      | .662    |
| Radiating pain of the lower limb | 5 (31.3)    | 4 (40)      | .974    |
| Intermittent claudication | 7 (43.8)    | 3 (30)      | .774    |
| Saddle anaesthesia       | 1 (6.3)      | 1 (10)      | .684    |
| Preoperative imaging findings [cases (%)] |             |             |         |
| Obvious presacral abscesses | 6 (37.5)    | 3 (30)      | .696    |
| Sinus formation          | 0            | 0           | —       |

Abbreviations: IS, iliac screw; L3-S2 (I), fixed from L3 to S2 (ilium); S2AI: second sacral alar iliac screw.
| Table 2 | Comparison of the operation results between the S2AI and IS groups (±s) |
|---------|---------------------------------------------------------------------|
|         | **S2AI (n = 16)** | **IS (n = 10)** | **P-value** |
| Operation time (min) | 202.5 ± 32.3 | 287.1 ± 49.8 | .048 |
| Blood loss (mL) | 270.6 ± 198.3 | 514.2 ± 219.6 | .042 |
| Total drainage (ml) | 509.0 ± 181.4 | 538.5 ± 158.8 | .677 |
| Extubation time (d) | 3.2 ± 0.7 | 3.3 ± 0.5 | .698 |
| Length of hospitalisation (d) | 13.3 ± 1.8 | 14.5 ± 2.4 | .159 |
| Fusion time (mo) | 7.0 ± 1.7 | 7.1 ± 2.2 | .699 |

| Table 3 | Comparison of the ESR, CRP, and VAS scores and the ODI and ambulatory status scores between the S2AI and IS groups (±s) |
|---------|---------------------------------------------------------------------|
|         | **S2AI (n = 16)** | **IS (n = 10)** | **P-value** |
| ESR (mm/h) | | | |
| Preoperatively | 72.6 ± 20.9 | 69.7 ± 24.1 | .748 |
| 1 wk after surgery | 27.3 ± 6.8* | 31.9 ± 7.5* | .120 |
| 1 mo after surgery | 21.2 ± 4.7* | 20.2 ± 4.6* | .604 |
| 6 mo after surgery | 18.7 ± 9.0* | 21.6 ± 14.1* | .531 |
| 1 y after surgery | 10.9 ± 4.7* | 12.1 ± 5.4* | .551 |
| Last follow-up | 6.3 ± 2.7* | 7.9 ± 4.2* | .247 |
| CRP (mg/L) | | | |
| Preoperatively | 84.2 ± 35.3 | 80.8 ± 28.4 | .800 |
| 1 wk after surgery | 33.9 ± 8.2* | 29.7 ± 11.5* | .287 |
| 1 mo after surgery | 19.2 ± 11.0* | 18.0 ± 11.9* | .798 |
| 6 mo after surgery | 9.3 ± 6.3* | 9.6 ± 6.0* | .917 |
| 1 y after surgery | 5.6 ± 2.6* | 5.1 ± 3.0* | .661 |
| Last follow-up | 2.4 ± 1.2* | 3.1 ± 2.2* | .302 |
| VAS score | | | |
| Preoperatively | 6.3 ± 3.1 | 5.7 ± 2.5 | .611 |
| 1 wk after surgery | 2.9 ± 1.8* | 2.5 ± 1.4* | .556 |
| 1 mo after surgery | 2.7 ± 1.0* | 3.3 ± 0.9* | .160 |
| 6 mo after surgery | 2.0 ± 0.8* | 2.5 ± 0.5* | .083 |
| 1 y after surgery | 1.6 ± 0.6* | 2.1 ± 0.7* | .083 |
| Last follow-up | 1.6 ± 0.9* | 1.9 ± 0.8* | .398 |
| ODI score | | | |
| Preoperatively | 32.1 ± 5.3 | 29.4 ± 4.6 | .313 |
| 1 wk after surgery | 8.5 ± 4.6* | 7.9 ± 3.6* | .729 |
| 1 mo after surgery | 7.3 ± 1.4* | 8.1 ± 1.3* | .144 |
| 6 mo after surgery | 6.1 ± 1.0* | 6.8 ± 1.1* | .133 |
| 1 y after surgery | 4.9 ± 0.9* | 4.7 ± 0.8* | .464 |
| Last follow-up | 3.9 ± 3.1* | 4.3 ± 3.4* | .760 |
| Ambulatory status score | | | |
| Preoperatively | 2.5 ± 0.9 | 2.7 ± 1.3 | .646 |
| 1 wk after surgery | 2.8 ± 1.2 | 3.0 ± 1.3 | .692 |
| 1 mo after surgery | 2.9 ± 1.0 | 3.2 ± 0.8 | .488 |
| 6 mo after surgery | 3.3 ± 0.8* | 3.5 ± 0.5* | .575 |
| 1 y after surgery | 3.6 ± 0.7* | 3.6 ± 0.5* | .925 |
| Last follow-up | 3.7 ± 0.2* | 3.6 ± 0.3* | .316 |

Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; IS, Iliac screw; ODI, Oswestry Disability Index; S2AI, Second sacral alar iliac screw; VAS, visual analogue scale.

*P < .05 compared with preoperatively.
The cohort consisted of 15 males and 11 females, aged 23 to 75 years (mean age, 52.1 ± 17.1 years). The baseline characteristics are shown in Table 1. There was no significant difference between the two groups in the baseline clinical characteristics.

Preoperative imaging showed that 9 (34.6%) patients had obvious presacral abscesses, while the remaining patients had smaller abscesses. Computed tomography (CT) scans showed that the lesions involved 35 intervertebral spaces, and an obvious sequestrum was present in 19 of the intervertebral spaces. No sinus formation occurred in this cohort (Table 1).

### 3.2 Operative data

The surgical details of the patients are shown in Table 2. Analysis of the operative data suggested that the S2AI group had significantly shorter total operative times (202.5 ± 32.3 minutes vs 287.1 ± 49.8 minutes, \(P = .04\)) and less blood loss (270.6 ± 198.3 mL vs 514.2 ± 219.6 mL, \(P = .04\)) than that in IS group, and no difference was observed in the length of hospitalisation (\(P > .05\)).

### 3.3 Clinical outcomes

The mean duration of follow-up was 23.8 ± 3.65 (range, 20–38) months. The mean period of graft union was 7.0 ± 1.7 (range, 5–12) months for the S2AI group, and 7.1 ± 2.2 (range, 6–11) months for the IS group, with no significant difference between groups (\(P > .05\)). Compared to the scores before surgery, statistically significant improvements in the erythrocyte sedimentation rate (ESR) level, C-reactive protein (CRP) level, VAS scores, ODI, and SF-36 scores were achieved in both groups at 1 week, 1 month, 6 months postoperatively and at the final follow-up (\(P < .05\), Tables 3 and 4). The ESR level, CRP level, VAS scores, ODI, and SF-36 scores were compared between the two groups at each observation time point, and no statistically significant differences were identified (\(P > .05\)).

### 3.4 Postoperative complications

The summary of complications in each group was presented in Table 5. No delayed wound healing or poor healing occurred in either group. No statistically significant differences were identified in the incidence of sacroiliac joint pain between the two groups (\(P > .05\)). The incidences of implant failure and reoperation were slightly lower in the S2AI group than in the IS group, and the incidences of sinus formation and pseudarthrosis were slightly higher in the S2AI group than in the IS group; however, no significant differences were observed (\(P > .05\)). Symptomatic screw prominence occurred more significantly frequently in the IS group than in the S2AI group (\(P < .05\)). The postoperative imaging examination suggested that the screw position was not ideal in 3 (11.5%) patients (2 (12.5%) patients in the S2AI group and 1 (10.0%) patients in the IS group), and visceral, vascular, or nerve injuries were not found in either group. There was only 1 (10.0%) patient who suffered decompenation of cardiac insufficiency in the IS group after the operation.

### Table 4 Comparison of the SF-36 scale scores between the S2AI and IS groups (±s)

|                           | S2AI (n = 16) | IS (n = 10) | \(P\)-value |
|---------------------------|---------------|-------------|-------------|
| **Physical function (PF)**|               |             |             |
| Preoperatively            | 67.2 ± 7.1    | 71.2 ± 7.8  | .191        |
| Last follow-up            | 79.8 ± 3.2*   | 81.8 ± 3.1* | .130        |
| **Role-physical (RP)**    |               |             |             |
| Preoperatively            | 53.8 ± 3.3    | 55.1 ± 4.2  | .387        |
| Last follow-up            | 73.1 ± 3.6*   | 74.6 ± 4.4* | .352        |
| **Bodily pain (BP)**      |               |             |             |
| Preoperatively            | 42.9 ± 4.5    | 46.1 ± 6.2  | .140        |
| Last follow-up            | 72.9 ± 4.5*   | 73.3 ± 4.4* | .826        |
| **General health (GH)**   |               |             |             |
| Preoperatively            | 66.2 ± 6.7    | 64.7 ± 5.2  | .553        |
| Last follow-up            | 79.1 ± 4.6*   | 78.3 ± 3.9* | .652        |
| **Vitality (VT)**         |               |             |             |
| Preoperatively            | 56.1 ± 6.2    | 57.8 ± 7.6  | .539        |
| Last follow-up            | 72.6 ± 6.9*   | 73.7 ± 4.8* | .664        |
| **Social function (SF)**  |               |             |             |
| Preoperatively            | 55.9 ± 4.4    | 56.8 ± 5.6  | .652        |
| Last follow-up            | 77.8 ± 3.4*   | 76.9 ± 4.3* | .559        |
| **Role-emotional (RE)**   |               |             |             |
| Preoperatively            | 58.4 ± 5.7    | 60.7 ± 5.1  | .308        |
| Last follow-up            | 79.6 ± 3.4*   | 76.9 ± 4.3* | .088        |
| **Mental health (MH)**    |               |             |             |
| Preoperatively            | 63.4 ± 6.1    | 62.9 ± 5.2  | .832        |
| Last follow-up            | 80.7 ± 3.9*   | 78.2 ± 4.3* | .139        |

Abbreviations: IS, iliac screw; S2AI, second sacral alar iliac screw. *\(P < .05\) compared with preoperatively.
DISCUSSION

Lumbosacral tuberculosis with severe destruction of the vertebrae can lead to low back pain, hypolordosis or kyphosis with altered lumbosacral biomechanics, and neurological deficits (ie, sciatica, motor weakness of the lower limbs, or bowel/bladder dysfunction). However, the surgical treatment of lumbosacral tuberculosis with severe complications remains challenging because of the unique anatomic and biomechanical characteristics in this region. Several surgical modalities have been previously introduced and shown to be effective for the treatment of lumbosacral tuberculosis, but the optimal surgical strategy was still controversial. In the 1950s, Hodgson and Stock introduced anterior debridement and arthrodesis for spinal tuberculosis; then, the ‘Hong Kong operation’ was long considered to be the ‘gold standard’ because it allowed direct access to the focus and facilitates restoration of spinal stability. However, inadequate kyphosis correction, increased risk of iliac vessels injury, and retrograde ejaculation were major drawbacks of this approach when it was performed in the lumbosacral region. Moreover, several anterior lumbosacral fixation plates have been designed for L5-S1 tuberculosis; nevertheless, those fixation devices might have lower mechanical strength than the posterior pedicle screw system, especially for patients with severe destruction of the L5 and S1 vertebrae. In recent years, the posterior-only approach has gained increased popularity due to its advantages of circumferential decompression of neural elements along with three-column fixation and effective kyphosis correction attained via pedicle instrumentation. However, for patients with severe destruction of the S1 vertebra, the integrity and stability of the pelvic ring will be seriously affected after debridement, lumbo pelvic fixation was generally necessary because it was difficult to achieve sufficient biomechanical strength with S1 pedicle screws, and they were more prone to failure.

In recent decades, many lumbopelvic fixation strategies have been attempted, but only the Galveston technique, ISs, and S2AI screws are still widely used. Traditional IS fixation has several limitations, including high prominence, a need for additional connectors, and extensive dissection of tissue. Therefore, the S2AI technique developed by Kebaish et al has become one of the most widely used modalities for lumbopelvic instrumentation in recent years. An increasing number of studies have demonstrated that S2AI instrumentation was superior to IS instrumentation in terms of implant prominence, soft tissue dissection, and convenient assembly. In this study, we adopted the posterior-only approach with the S2AI and IS fixation techniques for the treatment of lumbosacral tuberculosis. To the best of our knowledge, this is the first study to evaluate the feasibility and clinical outcomes of S2AI and IS techniques for lumbopelvic reconstruction in lumbosacral tuberculosis patients.

### TABLE 5
Comparison of complications between the S2AI and IS groups [cases (%)]

| Complications                              | S2AI (n = 16) | IS (n = 10) | P-value |
|--------------------------------------------|---------------|-------------|---------|
| Recurrence of tuberculosis                 | 3 (18.8)      | 2 (20.0)    | .665    |
| Temporary tuberculous sinus                | 3 (18.8)      | 1 (10.0)    | .966    |
| Pseudarthrosis                             | 2 (12.5)      | 1 (10.0)    | .662    |
| Internal fixation failure                  | 1 (6.3)       | 1 (10.0)    | .684    |
| Reoperation                                | 2 (12.5)      | 1 (10.0)    | .662    |
| Delayed wound healing or poor healing      | 0 (0)         | 0 (0)       | —       |
| Sacroiliac joint pain                      | 3 (18.8)      | 2 (20.0)    | .665    |
| Symptomatic screw prominence               | 0 (0)         | 8 (80.0)    | .000    |
| Complications of pelvic viscera            | 0 (0)         | 0 (0)       | —       |
| Nerve damage                               | 0 (0)         | 0 (0)       | —       |
| Vascular injury                            | 0 (0)         | 0 (0)       | —       |
| Non-invasive misplaced screw               | 2 (12.5)      | 1 (10.0)    | .662    |
| Postoperative complications                |               |             |         |
| Pulmonary embolism                         | 0             | 0           | —       |
| Deep vein thrombosis                       | 0             | 0           | —       |
| Cardiogenic complications                  | 0             | 1 (10.0)    | .219    |
| Intestinal obstruction                     | 0             | 0           | —       |

Abbreviations: IS, iliac screw; S2AI, second sacral alar iliac screw.
The incidence of lumbosacral tuberculosis is low, and in most cases can be cured by strict chemical therapy, but some patients will develop loss of lumbar lordosis and local kyphosis. General surgical methods of lumbosacral tuberculosis are selected according to the scope of lesion involvement, spinal canal involvement, nerve damage degree, and patient’s general condition. Currently, the commonly used surgical methods for lumbosacral tuberculosis include: (a) simple anterior debridement and bone grafting and internal fixation; (b) posterior debridement bone grafting combined with pedicle screw internal fixation; and (c) posterior pedicle screw fixation combined with anterior and posterior approaches for lesion removal and bone graft fusion. In clinical practice, due to the complex anterior anatomy and many complications, one-stage posterior lesion removal intervertebral bone grafting, and lumbosacral pedicle screw fixation were selected. However, due to the special anatomical characteristics of the lumbosacral segment, the vertebral bone defect after removal of the lesion and the stability of the fixation system for lumbosacral segment reconstruction is not good. Therefore, complications such as nail pulling and screw loosening are easy to occur. In order to achieve a more robust biomechanical effect, the sacral pelvis is often fixed intraoperatively to achieve enhanced internal fixation. IS fixation can meet the biomechanical requirements of the spine and pelvis, but due to the high notch of the screw, additional incisions are required to reveal the screw position, and there are many complications related to screw placement. In addition, the low content of cortical bone in the nail canal makes it difficult to provide sufficient distal anchoring force when applied to long segmental spinal and pelvic fixation, resulting in a high rate of screw loosening and lumbosacral pseudo joint formation. S2AI screws were first proposed by Chang and Sponseller et al.\textsuperscript{26} The indications of S2AI fixation are as follows: the tuberculosis focus was in the L5/S1 intervertebral disc and S1 vertebral body was severely damaged and nails could not be placed, or the mechanical strength of L5-S1 short segment fixation was not enough to support reconstruction in patients with severe osteoporosis. The S2AI screw has a lower notch and does not require additional incisions. The screw and the S2AI screw are in a line of force and do not require additional transverse linking devices. It stabilises both the sacrum and the iliac crest with three cortical screws, providing sufficient biomechanical strength without affecting the posterior superior crest of the iliac crest from the body bone.

Previous studies have reported that S2AI technology was more convenient than IS fixation, with less extensive dissection of tissue and fewer complications. The current study demonstrated that the operation time and intraoperative blood loss were significantly lower in the S2AI group than in the IS group ($P < .05$, Table 2). The results indicated that the S2AI technique typically involves less soft tissue dissection and convenient assembly, leading to less trauma than the IS technique. And no significant difference was observed in bone fusion time.

Theoretically, due to the penetration of the tricortical layers, namely, the bicortical layers of the sacrum and a monocortical layer of ilium, immediate stability, and sufficient biomechanical strength can be obtained via the S2AI technique.\textsuperscript{29} This study confirmed that S2AI screw and IS placement are both reliable techniques for providing a stable biomechanical environment for lumbosacral tuberculosis patients. Both the S2AI technique and the IS technique achieved significant pain relief and functional recovery with similar incidences of L5-S1 pseudarthrosis. Compared to the VAS and ODI scores before the operation, the scores of the two groups at 7 days after the operation and at the last follow-up visit were significantly improved and showed no significant intergroup differences, indicating that the two different fixation techniques did not affect the improvement of postoperative conditions and that good clinical efficacy could be obtained with either technique. The SF-36 scale is one of the most commonly used standardised measurement tools for quality of life and can provide information on all aspects of health.\textsuperscript{30} The scores for the eight dimensions of the SF-36 scale were significantly improved at the last follow-up visit, indicating that both fixation techniques improved the patients’ clinical symptoms and quality of life.

Satisfactory outcomes have been reported previously, but complications following lumbopelvic instrumentation remain a major concern. Compared to IS placement, the S2AI screw technique can significantly reduce implant prominence and postoperative discomfort, which was consistent with the results reported by Elder et al.\textsuperscript{15} However, no significant difference was observed in the incidence of sacroiliac joint pain between the two groups. Because many factors affected sacroiliac joint pain, and no uniform diagnostic criteria existed, this pain cannot be explained by a single aspect.\textsuperscript{17} We believed that the S2AI screw technique, which involves less lateral soft tissue dissection, can reduce sacroiliac joint pain. However, S2AI screw fixation through the sacroiliac joint surface causes damage to the articular cartilage and contributes to sacroiliac joint pain, and this damage is difficult to determine via imaging examination. Therefore, the clinical and imaging evidence for sacroiliac joint pain should be further studied. In addition, no significant differences were found between the two groups in the incidence of pseudarthrosis formation and internal fixation failure. Except for one patient in the IS group who had a history
of coronary stent surgery and suffered cardiac insufficiency postoperatively, no complications, such as delayed wound healing, screw-related vascular injury, neurological injury, visceral injury, pulmonary embolism, deep vein thrombosis, intestinal obstruction, or other perioperative complications, were evident in the patients, suggesting that the S2AI screw technique has the same level of safety as the IS technique. S2AI screw placement has been reported to be the direct cause of injury to the superior gluteal artery.31 During the S2AI screw placement process, the risk of injury to the superior and superficial branches of the superior gluteal artery increased.32 However, other scholars have studied the anatomical relationship between the S2AI screw, adjacent structures and the clinical effect of the S2AI screw, and concluded that no relevant visceral, neurological, or vascular damage occurs during S2AI screw placement.33-35 In this study, no related vascular or neurological complications occurred. However, an adequate preoperative measurement was essential to minimise the risk of superior gluteal artery injury.

One of the limitations was that the data were obtained from a single centre in a retrospective manner, and the sample size was relatively small, which may weaken the generalisability of the results. The other limitation was that additional bias may also be introduced due to temporal differences in treatment. In the further study, we will adopt a prospective study with a larger sample to verify the conclusion.

5 | CONCLUSIONS

Both the IS and S2AI fixation techniques can achieve satisfactory outcomes for the restoration of lumbosacral stability of lumbosacral tuberculosis. Furthermore, compared to the traditional IS fixation technique, the S2AI fixation technique can shorten operation time and reduce surgical trauma for the treatment of lumbosacral tuberculosis.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

All authors have read and approved the manuscript, and significantly contributed to this paper. Long Yu: Conception and design, literature review, data collection, data analysis, manuscript writing. Litao Li: Conception and design, literature review, data collection, data analysis, manuscript writing. Dawei Li: Conception and design, literature review, data collection, data analysis, manuscript writing. Zhanpeng Luo: Data collection, data analysis, manuscript revising. Ning Liu: Data collection, data analysis, manuscript revising. Yunfeng Wu: Data collection, data analysis, manuscript revising. Da Bao: Data collection, data analysis, manuscript revising. Xu Cui: Data collection, data analysis, manuscript revising.

CONSENT FOR PUBLICATION

Written informed consent was obtained from the patient for publication.

DATA AVAILABILITY STATEMENT

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

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