Minimally Invasive versus Conventional Open Surgery for Fixation of Spinal Fracture in Ankylosed Spine

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INTRODUCTION

Spinal fractures in ankylosing spondylitis (AS) patients are four times more common than the general population with lifetime incidence ranging from 5% to 15%56. Seventy percent of vertebral fractures in AS were associated with spinal cord injury at initial presentation following a trauma5. Mortality rates ranged from 7 to 32%56. Patients with diffuse idiopathic skeletal hyperostosis (DISH) had up to 1.5 times higher prevalence of vertebral fractures7. Conservative treatment plays little role in these fractures due to the long lever arm forces exerted at the fracture site. Nonsurgical treatment was associated with higher risks of complications such as pulmonary complications, thromboembolism and decubitus ulcers8. Therefore, many authors had described various surgical techniques such as posterior approach or combined anterior-posterior approach. However, posterior spinal stabilisation remains the most favored option5,9,10,11. Although combined anterior-posterior technique is advantageous from a biomechanical standpoint, it poses higher surgical risks12. In contrast, open surgery utilising posterior approach requires polysegmental long-construct instrumentation to counteract the forces acting at the fracture site. The role of minimally invasive stabilisation (MIS) using percutaneous pedicle screws (PPS) for vertebral fractures in ankylosed spine has not been elucidated. Previous reports on the role of MIS using PPS showed lower surgical risks i.e. reduced blood loss and operation time, but, in their report, only short segment stabilisation was investigated13,14. Recently, the use and advantages of long construct MIS using PPS in traumatic fractures and spinal metastasis have been investigated15-17. In this study, we would like to report the outcome of long construct MIS using PPS in the treatment of hyperextension spinal fractures in the ankylosed spine.

Keywords:
minimally invasive spinal stabilisation, long construct fixation, open surgery, spinal fracture, ankylosed spine

ABSTRACT

Introduction: This was a retrospective study aimed to investigate the perioperative outcomes of long construct minimally invasive spinal stabilisation (MIS) using percutaneous pedicle screws (PPS) versus conventional open spinal surgery in the treatment of spinal fracture in ankylosing spondylitis (AS) and diffuse idiopathic skeletal hyperostosis (DISH).

Material and Methods: Twenty-one patients with AS and DISH who were surgically treated between 2009 and 2017 were recruited. Outcomes of interest included operative time, intra-operative blood loss, complications, duration of hospital stay and fracture union rate.

Results: Mean age was 69.2 ± 9.9 years. Seven patients had AS and 14 patients had DISH. 17 patients sustained AO type B3 fracture and 4 patients had type B1 fracture. Spinal trauma among these patients mostly involved thoracic spine (61.9%), followed by lumbar (28.6%) and cervical spine (9.5%). MIS using PPS was performed in 14 patients (66.7%) whereas open surgery in 7 patients (33.3%). Mean number of instrumentation level was 7.9 ± 1.6. Mean operative time in MIS and open group was 179.3 ± 42.3 minutes and 253.6 ± 98.7 minutes, respectively (p=0.028). Mean intra-operative blood loss in MIS and open group was 185.7 ± 86.4ml and 885.7 ± 338.8ml, respectively (p=0.001). Complications and union rate were comparable between both groups.

Conclusion: MIS using PPS lowers the operative time and reduces intra-operative blood loss in vertebral fractures in ankylosed disorders. However, it does not reduce the perioperative complication rate due to the premorbid status of the patients. There was no significant difference in the union rate between MIS and open surgery.
MATERIALS AND METHODS

We retrospectively reviewed patients with AS and DISH who were treated for spinal fractures in a single tertiary institution from 2009 to 2017. Ethical approval was obtained. Inclusion criteria were patients who had underlying AS or DISH, who presented with vertebral fractures and treated with a long construct spinal fixation (stabilization of at least three levels above and three levels below the fractured vertebra), either by open surgery or MIS (Fig. 1). All patients underwent a computed tomography (CT) scan of the spine prior to surgery. A total of 21 patients were included.

All patients were positioned prone on a four-post frame on a Jackson table to allow good visualisation of the spinopelvic anatomy on anteroposterior (AP) and lateral fluoroscopic views. One of the most important surgical pitfalls in AS and DISH surgery is sagittal malalignment and neurological injury during positioning and surgery. Careful, gentle positioning of a patient with an ankylosed spine is extremely important as excessive movement over the fracture site can lead to sagittal malalignment and neurological injury. In patients with hyperkyphosis, a Wilson frame might be useful to accommodate the kyphotic alignment of the spine. The height of the Wilson frame can be adjusted to allow in-situ fusion while preventing sagittal malalignment and fracture displacement which may cause neurological injury. PPS were performed simultaneously on both sides by two surgeons.

A true AP view of the corresponding vertebra was obtained, in which both superior and inferior endplates were parallel and both pedicles were equidistant from the spinous process (Fig. 2a). A skin incision of 2cm was made just lateral to the lateral edge of the pedicle for the thoracic spine and 1-2cm lateral to the lateral border of the pedicle in the lumbar spine. The fascia was incised, and the muscles were split parallel to its fibers. Two 11G trocars were positioned at the lateral edge of the pedicle (right: 3 o’clock, left: 9 o’clock) (Fig. 2b). However, different starting point were chosen for the upper thoracic level, T1-T6 vertebrae (right: 2 o’clock, left: 10 o’clock) as described by Kwan et al.18 The trocar was then advanced until the tip of the trocar approached the medial wall of the pedicle on AP view (Fig. 2c). A lateral view was obtained. On the lateral view, the tip of the trocar should be at or slightly deeper than the posterior vertebral border (Fig. 2d). The trocar was then advanced until the middle of the vertebral body (Fig. 2e). A guide wire was inserted. The screw was then inserted along the direction of the guide wire, while avoiding inadvertent guide wire advancement (Fig. 2f). Once the screw position was confirmed with the lateral fluoroscopic image, the guide wire was removed. Similar steps were repeated for the rest of the planned instrumentation vertebrae (Fig. 3a).

For open surgery, the pedicle screws were inserted using ‘free-hand technique’ in the thoracic and lumbar spine. In the cervical region, lateral mass screws were inserted.

Rods were contoured to allow in situ fixation of the fractured vertebra without any correction of preexisting deformity. To allow in situ fixation, we have developed an extension of the screw sleeve that would mimic the final position of the rod when seated in the screw head. The rod was then contoured with all screw sleeves and extensions positioned in a parallel alignment. At the proximal thoracic junction, rods were inserted from a caudal to cephalad direction whereas for the thoracolumbar or lumbosacral junction, rods were inserted from a cephalad to caudal direction (Fig. 3b). Nuts were inserted. Final tightening of the whole construct was performed (Fig. 3c) and lastly, deep fascia and skin were closed.

Post-operatively, patients with intact neurology were allowed to sit up and to ambulate to washroom with an external brace once the pain was tolerable. Continuous bladder drainage tube was removed when patients start to ambulate. Post-operative analgesia comprised of patient-controlled analgesia with morphine, oral celecoxib and acetylsalicylic acid. On day 2 or 3 post-operatively, surgical wounds were inspected. All patients were required to wear an external brace for three months. In the presence of neurological deficit, the post-operative rehabilitation protocol was decided by the spine rehabilitation team. AP and lateral standing radiographs were taken before discharge (Fig. 4).

All patients underwent CT scans between four to six months post-operatively. Fracture union was assessed based on the sagittal, coronal as well as axial images. A fracture union was defined as presence of bridging trabeculae across the fracture site within the vertebral body or formation of marginal or non-marginal syndesmophytes across two vertebral levels (Fig. 5).

Data collected included age, gender, diagnosis, level of injury, fracture type according to AO classification, type of surgery (open surgery or MIS), level of instrumentation, number of instrumentation levels, pre-operative and post-operative neurological function according to Frankel grade, American Society of Anesthesiologist Physical Status Classification (ASA) and Charlson comorbidity index (CCI). The perioperative outcomes that were recorded included operative time, intra-operative blood loss, complications, duration of hospital stay and union rate.

Student’s t-test was used for comparison of continuous variables while chi-squared tests were used for comparison of categorical variables between open surgery and MIS. Statistical analysis was performed using IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, N.Y., USA) with statistical significance, p value <0.05.
Table I: Demographic Data of Patients Treated with Open Surgery or MIST

| Age (years) | Open (n=7) | MIST (n=14) | Overall (n=21) | p value |
|-------------|------------|-------------|----------------|---------|
|             | 69.3±11.5  | 69.1±9.5    | 69.2±9.9       | 0.976   |
| Gender (n(%)| M: 6(85.7) | 9(64.3)     | 15(71.4)       | 0.613   |
|             | F: 1(14.3) | 5(35.7)     | 6(28.6)        |         |
| Level of injury (n(%)|          |             |                |         |
| Cervical    | 2(28.6)    | 0(0)        | 2(9.5)         | 0.028   |
| Thoracic    | 4(57.1)    | 9(64.3)     | 13(61.9)       |         |
| Lumbar      | 1(14.3)    | 5(35.7)     | 6(28.6)        |         |
| Diagnosis (n(%)|          |             |                |         |
| AS          | 3(42.9)    | 4(28.6)     | 7(33.3)        | 0.638   |
| DISH        | 4(57.1)    | 10(71.4)    | 14(66.7)       |         |
| AO Classification |          |             |                |         |
| B1          | 2(28.6)    | 2(14.3)     | 4(19.0)        | 0.574   |
| B3          | 5(71.4)    | 12(85.7)    | 17(81.0)       |         |
| AO Classification (n(%)|        |             |                |         |
| AS          | 7.7±1.7    | 7.9±1.5     | 7.9±1.6        | 0.775   |
| DISH        | 2.5±0.6    | 2.2±0.6     | 2.3±0.6        | 0.386   |
| CCI         | 3.3±1.1    | 3.4±1.6     | 3.4±1.4        | 0.831   |

Abbreviations: AS = ankylosing spondylitis; DISH = diffuse idiopathic skeletal hyperostosis; ASA = American Society of Anesthesiologist Physical Status Classification; CCI = Charlson Comorbidity Index

Table II: Patients’ Demographic and Surgical Details

| No | Age (years) | Gender | Diagnosis/ Fracture level | Type of Surgery | Instrumentation Level | Number of levels | Pre-op Frankel | Post-op Frankel | Follow-up (month) | Complications |
|----|-------------|--------|----------------------------|-----------------|----------------------|-----------------|----------------|-----------------|------------------|---------------|
| 1  | 69          | M      | AS/ T4                     | Open            | T1-T7                | 7               | E              | E               | 99               | -             |
| 2  | 64          | M      | DISH/ T11/12 disc          | Open            | T9-L2                | 6               | E              | E               | 90               | -             |
| 3  | 50          | M      | AS/ C7/T1 disc            | Open            | C3-T6                | 11              | A              | A               | 66               | -             |
| 4  | 86          | M      | DISH/ T10                 | Open            | T7-L1                | 7               | D              | D               | 14               | PUD           |
| 5  | 65          | F      | AS/ C4/5 disc             | Open            | C2-T3                | 9               | C              | D               | 34               | -             |
| 6  | 79          | M      | DISH/ C6                  | Open            | C3-T2                | 7               | C              | C               | -                | HAP, deceased |
| 7  | 72          | M      | DISH/ L2                  | Open            | T11-L5               | 7               | E              | E               | 45               | -             |
| 8  | 53          | M      | AS/ T12                   | MIST            | T8-L3                | 8               | E              | E               | 20               | -             |
| 9  | 82          | F      | DISH/ L1                  | MIST            | T7-L4                | 10              | D              | D               | 60               | -             |
| 10 | 81          | F      | DISH/ T10                 | MIST            | T7-L1                | 7               | C              | D               | 19               | -             |
| 11 | 52          | M      | AS/T10/11 disc            | MIST            | T7-L2                | 8               | D              | D               | 17               | Delayed union |
| 12 | 70          | M      | DISH/ L1                  | MIST            | T9-L4                | 8               | D              | D               | 15               | NSTEMI        |
| 13 | 80          | F      | DISH/ L2                  | MIST            | T9-L5                | 9               | D              | D               | 15               | -             |
| 14 | 72          | M      | DISH/ T11                 | MIST            | T9-L1                | 5               | E              | E               | 13               | -             |
| 15 | 76          | F      | DISH/ T12                 | MIST            | T7-L3                | 9               | E              | E               | 8                | -             |
| 16 | 72          | M      | DISH/ T12                 | MIST            | T10-L3               | 6               | E              | E               | 6                | -             |
| 17 | 72          | M      | DISH/ T10/11 disc         | MIST            | T8-L3                | 8               | D              | D               | 35               | Epidural hematoma |
| 18 | 60          | M      | DISH/T3, T7               | MIST            | T1-T11               | 11              | C              | C               | 54               | -             |
| 19 | 67          | F      | AS/ L3                    | MIST            | T12-S1               | 7               | D              | D               | 7                | -             |
| 20 | 63          | M      | DISH/ T12                 | MIST            | T8-L3                | 8               | E              | E               | 53               | -             |
| 21 | 68          | M      | DISH/T1/2 disc            | MIST            | T10-L4               | 7               | E              | E               | 13               | -             |

Abbreviations: AS = ankylosing spondylitis, DISH = Diffuse idiopathic skeletal hyperostosis, PU D = peptic ulcer disease, HAP = hospital acquired pneumonia, NSTEMI = non-ST elevation myocardial infarction

Table III: Perioperative and post-operative details between open surgery and MIST

| Operation Time (min) | Open (n=7) | MIST (n=14) | Overall (n=21) | p value |
|----------------------|------------|-------------|----------------|---------|
| 253.6±98.7           | 179.3±42.3 | 204.1±73.3 | 0.028         |
| Blood loss (ml)      | 885.7±338.8| 185.7±86.4| 419.1±391.9  | 0.000   |
| Complication (n(%)   | 2(28.6)    | 2(14.3)    | 4(19.1)       | 0.574   |
| Union (n(%)          | 6/6(100)   | 13/14 (92.8)| 19/20 (95.0) | >0.999  |
| Hospital stay (days) | 42.0±25.4  | 21.2±16.5  | 28.1±21.7     | 0.057   |
| Study          | n   | Mean age (years) | Mean follow-up (month) | Diagnosis | Fracture level | Type of surgery | Number of instrumentation level (mean) | Operative time (min) | Blood loss (ml) | Post-operative LOS (days) | Complication          | Union (%) |
|----------------|-----|------------------|------------------------|-----------|----------------|----------------|----------------------------------------|---------------------|----------------|----------------------------|------------------------|-----------|
| Sapkas et al  | 20  | 56.0*            | 60.0                   | AS, T, L  | Open (PF +/- AF) | 4.0            | N/A                                    | N/A                 | N/A             | N/A                        | Screw loosening – 2; Infection – 1 | 100       |
| Lu et al      | 22  | 54.2             | 24.0                   | AS, T, L  | Open (PF +/- AF) | N/A            | N/A                                    | N/A                 | N/A             | N/A                        | RI – 2; Empyema – 1; Infection – 1 | 100       |
| Matthews et al| 6   | 63.0             | 30.0                   | AS, T, L  | Open (PF +/- AF) | N/A            | N/A                                    | N/A                 | N/A             | N/A                        | Multiple               | 100       |
| Kruger et al  | 10  | 81.5             | 7.9                    | AS & DISH | T, L            | MIST           | 3.6                                    | 60.2 (32 – 135)     | N/A             | 16.6 (8 – 22)              | ROI – 1; Budd Chiari (death) – 1; RI – 2; MI – 2 | N/A       |
| Yeoh et al    | 10  | 68.0             | 22.0                   | AS & DISH | N/A             | MIST           | 5.9                                    | N/A                 | N/A             | 24.0                       | HAP – 1                 | N/A       |
| Nayak et al   | 11  | 77.0             | 28.0                   | AS & DISH | T               | MIST           | 7                                      | 227.0 (79 – 449)    | N/A             | 14.4                       | Infection - 4          | 100       |
| Moussalem et al| 41 | 75.6             | 18.0                   | AS & DISH | T, L            | MIST (n=25) & Open (n=16) | N/A                      | 254.8 (MIST) 334.7 (Open) | 251 (25 – 900) | 166.8 (MIST) 1240.4 (Open) | Paraplegia – 2; Revision – 4 | N/A       |
| Bredin et al  | 31  | 75.1             | 35.6                   | AS, T, L  | MIST            | 5.2                                    | N/A                                    | N/A                 | N/A             | 5.96                       | Nil                     | 100       |
| Lindtner et al| 20 | 74.7             | 29.2                   | AS, T, L  | MIST (n=6) & Open (n=14) | N/A                      | N/A                                    | N/A                 | N/A             | N/A                        | Multiple               | N/A       |
| Okada et al   | 41  | 77.0             | N/A                    | DISH      | N/A             | MIST (n=16) & Open (n=25) | 5.1 (MIST) 4.9 (Open) | 168.1 (MIST) 224.6 (Open) 179.3 (MIST) | 133.9 (MIST) 499.9 (Open) 815.7 (Open) | N/A             | Multiple               | 100       |
| Current study | 21  | 69.2             | 35.3                   | AS, T, L  | DISH            | MIST (n=7) & Open (n=25) | 7.9                                    | 179.3 (MIST) 253.6 (Open) | 21.2 (MIST) 42.0 (Open) | N/A             | PUD – 1; HAP (death) – 1; MI – 1; EH – 1 | 95.0       |

*median
Abbreviations: n = sample size; LOS = length of stay; AS = ankylosing spondylitis; DISH = diffuse idiopathic skeletal hyperostosis; MIST = minimally invasive stabilisation; C = Cervical; T = Thoracic; L = Lumbar; PF = Posterior spinal fixation; AF = Anterior spinal fixation; N/A = not available; RI = respiratory insufficiency; ROI = removal of implant; MI = myocardial infarction; PUD = peptic ulcer disease; HAP = hospital acquired pneumonia; EH = epidural hematoma
Fig. 1: A 67-year-old lady with underlying ankylosing spondylitis presented with back pain and Frankel D neurology after a fall from standing height. Plain radiographs (a,b) and computed tomography (CT) scan (c,d) showed L3 hyperextension fracture. She has a history of C4/5 disc hyperextension fracture 2 years ago in which a long-construct posterior spinal fusion from C2 to T3 (9 instrumentation levels) was performed.

Fig. 2: (a) Intraoperative fluoroscopic images showing steps in performing percutaneous pedicle screw insertion. A true AP view of the corresponding vertebra was taken. (b) Two 11G trocars were positioned at the lateral edge of the pedicle. (c) The trocars were advanced until the tip of the trocars approached the medial wall of the pedicles. (d) On the lateral view, the tip of the trocars should be at or slightly deeper than the posterior vertebral border. (e) The trocars were advanced until the mid-vertebral body. (f) After inserting a guide wire, the screw was inserted along the direction of the guide wire.
Fig. 3: (a) Intraoperative images after insertion of all pedicle screws. (b) Rod was inserted from proximal end of the construct. (c) Fluoroscopic imaging showed in situ fixation of the fracture without any correction of preexisting deformity.

Fig. 4: (a) Immediate postoperative AP and (b) lateral plain radiographs of the same patient treated with MISt with percutaneous pedicle screws from T12 to S1.

Fig. 5: (a) CT scans showed acute hyperextension fracture evidenced by cortical breakage extending from the anterior vertebral border to the posterior vertebral border. (b) Four months postoperatively, fracture union was achieved evidenced by bridging trabeculae across the fracture site within the vertebral body (red arrow) and formation of syndesmophytes across 2 vertebral levels (yellow arrow).
RESULTS
The mean age for this cohort was 69.2 ± 9.9 years. The mean follow-up duration was 35.3 ± 27.8 months. There were 15 males and 6 females. Seven patients were diagnosed with AS, and 14 patients with DISH. There were 17 patients with AO B3 fracture and 4 patients with B1 injury. The most common involved region was thoracic spine (61.9%), followed by lumbar (28.6%) and cervical spine (9.5%). MISSt using PPS was performed in 14 patients (66.7%) whereas open surgery in seven patients (33.3%). The mean number of instrumentation level for open group and MISSt group was 7.7 ± 1.7 and 7.9 ± 1.5, respectively (p=0.775). The mean ASA score was 2.3 ± 0.6 and the mean CCI score was 3.4 ± 1.4. There was no significant difference between MISSt and open surgery groups in terms of age, gender, fracture type, number of instrumentation level, ASA and CCI score (Table I).

Table II outlines the details of individual patients including their age, type of surgery, instrumentation level, pre-operative and post-operative neurological status based on Frankel classification, duration of follow-up and complications.

Table III illustrates the perioperative outcomes of the study. The outcomes that demonstrated significant difference were operative duration and intra-operative blood loss. The mean operative duration for MISSt group was 179.3 ± 42.3 vs. 253.6 ± 98.7 minutes in the open surgery group (p=0.028). The mean intra-operative blood loss was almost five times lesser in the MISSt group (185.7 ± 86.4ml) compared to the open surgery group (885.7 ± 338.8ml) (p<0.001). The mean hospital stay in the open surgery group was 42.0 ± 25.4 days compared to 21.2 ± 16.5 days in the MISSt group (p=0.057).

Twelve patients (57.1%) presented with neurological deficit during admission. Among these twelve patients, eight underwent MISSt and four underwent open surgery. Among patients with neurological deficit, one patient (8.3%) was classified as Frankel A, four patients (33.3%) as Frankel C and seven patients (58.3%) as Frankel D. Among those with neurological deficit, two (16.7%) showed neurological improvement. Two patients (16.7%) improved one Frankel grade. Neurological status remained the same for other patients. There was no significant difference in neurological recovery comparing MISSt and the open surgery group. One patient with type B3 T10/T11 fracture, who underwent MISSt T8 to L3 complained of transient neurological deficits of both lower limbs secondary to an epidural hematoma. However, the neurological deficit recovered spontaneously to Frankel D (as it was pre-operatively) prior to discharge. 85.7% of patients were ambulant (Frankel D and E) pre and post-operatively.

There were two complications in each group. There was one mortality in the open surgery group compared to none in the MISSt group. The complications that were encountered included one case of upper gastrointestinal hemorrhage secondary to peptic ulcer disease (PUD), one case of hospital acquired pneumonia, one case of non-ST-elevation myocardial infarction (NSTEMI) and one case of epidural hematoma. An 86-year-old patient in the open surgery group developed upper gastrointestinal hemorrhage secondary to PUD on post-operative day 3. He remained hemodynamically stable with transfusion of three packs of allogeneic blood and medical therapy using proton pump inhibitors. A 79-year-old patient with C6 type B3 fracture with Frankel C neurological deficit underwent laminectomy C3 to C6 and instrumentation from C3 to T2, and developed hospital acquired pneumonia. Despite mechanical ventilation support post-operatively, he succumbed to death three months later. A 70-year-old patient with ischemic heart disease developed NSTEMI intra-operatively but was treated successfully with dual antiplatelet therapy.

Union rate was assessed in all patients except one in the open surgery group because of perioperative mortality. The remaining six patients (100%) in the open surgery group achieved union. In the MISSt group, 13 out of 14 patients (92.8%) achieved union. One patient developed delayed union (final follow-up at 17 months). However, there was no evidence of implant loosening during the final follow-up.

DISCUSSION
Both AS and DISH cause similar clinical manifestations; including spinal stiffness, increased bone fragility, and difficulty with balance and gaze resulting in a higher risk of vertebral fractures. Owing to the inherent instability of the spine resulting from ossification of surrounding soft tissues, vertebral fractures in the ankylosed spine are prone to neurological deficits. Conservative treatment plays little role and is associated with poorer outcomes with spinal malalignment and persistent instability resulting in neurological impairment.

Various surgical strategies have been described (Table IV). Few authors reported on outcomes of conventional open surgery. Sapkas et al performed open surgery in 20 patients; combined anterior-posterior approach in three and posterior approach in 17. All achieved union and 35% showed neurological improvement. Lu et al compared 14 AS patients treated with open surgery and 11 patients treated conservatively and found good results in the surgical group while 8 patients (72.7%) in the conservative group had pseudoarthrosis. However, Matthews et al compared six AS patients treated with posterior spinal fusion and five patients treated with orthosis and reported no difference.

The advent of MISSt using PPS in the treatment of vertebral fractures in ankylosing disorders has reduced the morbidity associated with open surgery such as increased blood loss, higher infection rate, longer operative time, higher pain
The number of instrumentation level was not fully investigated. Most studies only included short construct fixation (mean number of instrumentation level, Sapkas et al.: 4.0, Kruger et al.: 3.6, Yeoh et al.: 5.9 and Bredin et al.: 5.2). Only one study by Nayak et al. documented on the usage of a long-construct fixation of 7 instrumentation levels, however, no comparison with open surgery was reported. This current study reported the usage of long-construct MIST (mean number of instrumentation level: 7.9 ± 1.6) and its perioperative benefits compared to open surgery in managing vertebral fractures in ankylosed disorders. Due to the long lever arm created by multilevel fused segments over the fracture site, a long-construct fixation with superior biomechanical stability was favored.

There were some limitations in this study. The sample size was small because the incidence of vertebral fractures in ankylosing disorders was low. Secondly, post-operative functional outcomes of patients were not reported. Further studies should be organised prospectively to evaluate the long-term functional outcomes in this group of patients. Although there were no significant differences in patients’ demographics between patients who had MIST versus open surgery, this was a non-randomised sample. Further prospective randomised study might be more useful to investigate the true differences between MIST and open surgery in treating spinal fractures among patients with ankylosed spine.

CONCLUSION
MIST using PPS lowered the operative time and reduced intra-operative blood loss in fixation of vertebral fractures in AS and DISH. However, it did not reduce the perioperative complication rate because of the patients’ pre-morbid status. There was no significant difference in the union rate between MIST and open surgery.

CONFLICT OF INTEREST
The authors declare no conflicts of interest.
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