Surgical treatment of post-traumatic kyphosis using modified pedicle subtraction osteotomy

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Background data

Pedicle subtraction osteotomy (PSOS) is a pure closed wedge osteotomy that has been recently introduced for the correction of post-traumatic kyphosis (PTK). Modified PSOS uses the disc as part of the resected wedge together with the upper endplate, thus allowing excision of the degenerated disc material for better fusion and preventing failure. In PTK, the upper endplate is deficient and the upper disc is degenerated. Insertion of a spacer into the intervertebral gap ensures good bony contact and fusion and increases the angle of correction by making the correction in a manner of closed-open wedge rather than a pure closed wedge osteotomy.

Purpose

The aim of this work was to study the clinical and radiological results of surgical treatment of PTK using modified PSOS with insertion of a cage as a spacer into the intervertebral defect.

Study design

This was a prospective study conducted on 24 patients with symptomatic PTK.

Patients and methods

All patients were treated using the modified PSOS technique, with insertion of a cage into the intervertebral gap. Patients were assessed clinically and radiologically. Functional results were assessed using the Oswestry disability index (ODI) score and the Denis pain and work scale. Radiological assessment included local kyphosis angle and sagittal index immediately postoperatively and at the final follow-up, and the state of bony fusion and loss of correction at the last follow-up.

Results

The average follow-up period was 34.21 ± 4.47 (range 24–50 months). Local kyphosis angle improved from 39.08 ± 3.86° preoperatively to –0.25 ± 4.74° postoperatively, with insignificant change at the last follow-up. The sagittal index significantly improved from 41.33 ± 4.89° preoperatively to 1.81 ± 1.26° postoperatively, without significant change at the last follow-up. All patients showed solid bony fusion at the last follow-up. There were no major complications. All patients improved clinically as evidenced by improvement in pain and neurological status. Functional outcome significantly improved as evidenced by improvement in ODI score and return of most of the patients to their previous level of activity.

Conclusion

Modified PSOS is more anatomical, less technically demanding, and safe procedure that achieves good radiological and clinical outcomes with lower operative morbidity.

Keywords:

deficient upper endplate pedicle subtraction osteotomy, degenerated disc, modified pedicle subtraction osteotomy, post-traumatic kyphosis

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Introduction

Post-traumatic kyphosis (PTK) is one of the most common late complications of untreated or inadequately treated thoracolumbar spinal injuries. It has the potential of progression over time due to anterior shift of the line of gravity and weakening of the posterior erector spinae muscles [1] and may result in pain and neurological deterioration. Chronic dull aching pain usually starts at the level of the fracture due to muscle fatigue, nonunion, disc degeneration, or instability. The pain then originates from the adjacent levels above or below the deformity due to compensatory hyperextension and early development of degenerative arthritis of the facet joints [2,3]. Neurological deficits may be due to canal stenosis, tethering of the cord over the kyphos, increasing deformity, or development of post-traumatic syringomyelia [3].

Operative treatment of PTK is a challenge for spinal surgeons. The aim of surgical treatment of PTK regardless of the approach includes thorough decompression of the neural elements for neurogenic claudication or deficit, recreation of normal sagittal contours, and attainment of solid bony fusion. This can be achieved through an all-anterior, all-posterior, or combined anterior–posterior procedures [3]. Posterior-only surgery yields better therapeutic effect. In rigid sagittal plane deformities, different types of osteotomies are indicated and these include Smith-Peterson ostetomy (SPOS), pedicle subtraction osteotomy (PSOS), modified PSOS, vertebral column resection in very severe and rigid cases, and its modification, vertebral column decancelation.

PSOS is a three-column closing wedge osteotomy with favorable outcome by many studies for correction of rigid sagittal imbalance [4,5]. Recently, a few reports have recommended PSOS for correction of post-traumatic kyposis [3,5]. Modified PSOS is an osteotomy that includes excision of the disc and partial corpectomy of the upper part of the wedged body. It is a purely closing wedge osteotomy allowing shortening of the spine [6]. Modified PSOS is especially effective in post-traumatic cases, because the upper disc is degenerated and penetrating into the body, showing signs of instability, and is a source of nonunion and progression [6].

The aim of this study was to evaluate the clinical and radiological results of surgical treatment of post-traumatic angular kyphosis using the modified PSOS with insertion of a cage as a spacer into the intervertebral defect.

Patients and methods

From January 2007 to October 2008, 24 patients with symptomatic angular PTK were treated with modified PSOS and interbody cage at Mansoura University Hospital, Egypt. There were 15 male and nine female patients, whose ages ranged from 16 to 50 years (average 27.50 ± 9.90). The apex of deformity in most of the patients was at the thoracolumbar region (T_{12}–L_1) in 19 patients, L_2 in three patients, and L_3 in two patients. The duration between the initial trauma and the operation ranged from 6 to 72 months (average 22.21 ± 19.16). The route of injury was motor car accident in 14 patients and falling from height in 10 patients. The most common presentation was back pain in 16 patients. Neurological deficits were present in eight patients graded on the basis of the American Spinal Injury Association (ASIA) [7] scoring system as follows: three patients were of grade B, three of grade C, and two of grade D (Table 1).

The primary treatment was conservative in 18 patients. Anterior plate fixation was used in one patient and failed. Short-segment posterior pedicular screw and rod fixation was performed in five patients. The implant was removed early and resulted in collapse and kyphosis in one patient and implant failure occurred in four patients. Cases with osteoporotic fractures and those with severe collapse requiring total excision of the body together with the upper and lower discs were excluded from the study.

Table 1 Patients' characteristics and operative data

Case no.	Age (years)	Sex	Trauma	ASIA – neurological status	Duration	Region	LKA pre	SI pre	FU period	Operative time	Blood loss
1	17	Female	FFH	E	6	Th.L	37	37	50	180	900
2	28	Male	MCA	E	12	Th.L	40	40	40	155	850
3	45	Female	MCA	E	7	Th.L	38	38	30	160	800
4	17	Female	MCA	C	16	Th.L	36	36	48	150	700
5	24	Male	MCA	E	10	L	30	40	32	170	800
6	17	Female	FFH	E	6	Th.L	39	39	48	165	850
7	16	Female	MCA	B	10	Th.L	38	38	30	160	800
8	17	Male	FFH	E	28	Th.L	40	40	36	150	800
9	18	Female	FFH	E	9	L	32	42	30	160	1000
10	30	Male	MCA	B	8	L	35	45	25	155	950
11	17	Female	FFH	E	12	Th.L	38	38	24	160	750
12	43	Male	MCA	C	60	L	32	42	32	155	800
13	40	Male	MCA	C	72	Th.L	42	42	30	155	800
14	26	Male	FFH	E	10	Th.L	40	41	40	150	850
15	28	Male	MCA	E	16	Th.L	36	36	46	160	900
16	24	Female	FFH	E	12	Th.L	37	37	36	160	850
17	30	Male	MCA	E	15	Th.L	35	35	30	150	800
18	24	Male	MCA	E	12	L	37	47	26	160	900
19	30	Male	MCA	E	24	Th.L	40	40	30	140	950
20	50	Male	FFH	D	15	Th.L	36	36	32	145	950
21	22	Male	MCA	E	60	Th.L	33	33	30	150	800
22	25	Male	MCA	E	30	Th.L	38	38	36	135	950
23	32	Male	FFH	D	48	Th.L	30	36	32	160	1000
24	40	Female	FFH	B	35	Th.L	38	38	28	165	1000

ASIA, American Spinal Injury Association; FFH, falling from height; L, lumbar; LKA, local kyphosis angle; MCA, motor car accident; SI, sagittal index; Th.L, thoracolumbar junction (D_{12}–L_1).

All patients were evaluated clinically and radiologically preoperatively, immediately postoperatively, during follow-up visits, and at the final follow-up.

Preoperatively, radiological evaluation included standard AP and lateral plain radiographic films and dynamic flexion-extension films to assess the flexibility of kyphosis. CT scan with 3D reconstruction and MRI were used preoperatively.

Plain radiographs in AP and lateral views were used postoperatively and during follow-up periods.

Radiographic measurements were made from radiographs taken before surgery, immediately postoperatively, and at the final follow-up. Radiographic measurements included local kyphosis angle (LKA) measured as the angle between a line drawn along the superior endplate of the vertebra above and the lower endplate of the vertebra below. The sagittal index as described by Farcy *et al.* [8] was used to assess the actual segmental deformity at each vertebral level. Other assessed radiographic parameters included bony fusion, percentage of correction, loss of correction at the last follow-up, the presence of implant failure, and any complication. Fusion was diagnosed by the presence of bony trabeculae bridging into the endplates with absence of implant failure.

Clinical evaluation included neurological evaluation based on the ASIA scoring system [7] and perioperative and long-term complications. Functional outcome was assessed using the Oswestry disability index (ODI) questionnaire [9] and the Denis pain and work scale [10] for assessment of pain and physical activity at the final follow-up.

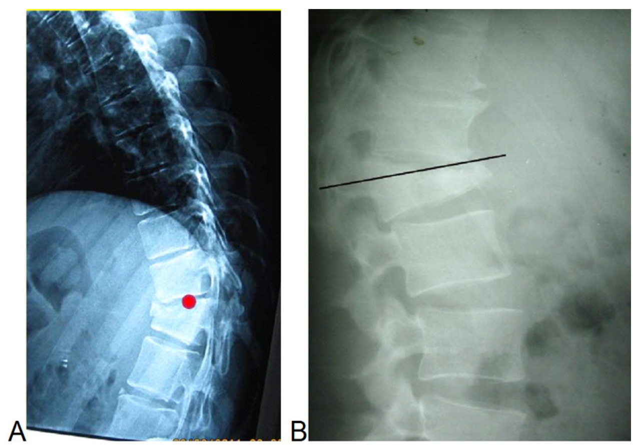
Statistical analysis

Data were analyzed using statistical package for social sciences, version 15. Qualitative data were presented as number and percentage. Comparison between groups was made using the χ^2-test. Data were presented as mean ± SD and range (minimum–maximum). The paired *t*-test was used for comparison within groups. A *P* value less than 0.05 was considered to be statistically significant.

Operative technique

Patients were operated in the prone position under general endotracheal hypotensive anesthesia. The spine was exposed by standard posterior midline skin incision with subperiosteal posterior and posterolateral exposure up to the tips of the transverse processes exposing two–three levels above and below the kyphos. Pedicle screws were inserted using a freehand technique above and below the target vertebrae perpendicular to the proximal and distal segments of the deformity and confirmed by fluoroscopy. Bilateral decompressive laminectomy, facetectomy, and total foraminal unroofing at the apex level was performed exposing the neural elements. The transverse processes (and rib heads) were excised exposing the lateral wall of the pedicle. Using the shavers of the TLIF technique, the upper disc was excised and the lower endplate of the vertebra above was prepared. Thereafter, a wedge of bone consisting of the upper endplate and the upper part of the pedicle on both sides was excised using osteotome, starting from the upper part or the middle of the pedicle based on the size of the angle of correction and directed toward the upper anterior endplate and ends in the disc space (Fig. 1). Finally, the posterior cortical shell of the upper part of the body was excised piecemeal using Rongeurs and pituitary forceps from under the cord. Local bone fragments were inserted and impacted anteriorly in front of the cage, and a cage filled with bone chips was inserted into the intervertebral gap. Pedicle screws can be inserted into the pedicle of the wedged body. Closure of the wedge was tried by manual approximation of the nearby screws and then closed with the slightly contoured rod using cantilever force until the endplates and the screws became horizontal and parallel. Bleeding from the epidural vessels and soft tissues was controlled using bipolar cautery and absorbable gelatin sponge (Gelfoam). Avoid overpenetration of the anterior cortex or excision of the anterior longitudinal ligament for the purpose of providing a hinge point to avoid translation and also for protection of the great vessels anteriorly. After closure of the osteotomy, the dura was inspected and palpated for any buckling or kinking below edges of the cephalic and caudal laminae. If this occurs, further partial laminectomy should be performed. The

Figure 1



(a) In post-traumatic kyphosis cases, the apex of deformity is at the level of the disc and upper endplate and the body is triangular in shape. (b) Direction of the osteotomy line.

wound was closed over drains. Postoperatively, the drain was removed when blood collection was less than 50 ml/24 h, usually on the third or fourth postoperative day. Patients were mobilized in a thoracolumbosacral orthosis.

Results

The average follow-up period was 34.21 ± 7.47 (range 24–50 months). The average operative time was 156.25 ± 9.47 (range 135–180 min). The average amount of blood loss was 864.58 ± 84.03 ml (700–1000 ml). There was significant reduction in the preoperative kyphotic angle and the sagittal index (P < 0.001) with insignificant changes at the last follow-up.

LKA improved from an average of 36.54 ± 3.23 (range 30–42°) preoperatively to an average of 1.15 ± 4.43 (range −8 to 6°) postoperatively (P < 0.001), with an average correction of 97.61 ± 12.87%. Loss of correction at the last follow-up was 0.13 ± 0.30° (range 0–1°) (Table 2).

Sagittal index also improved significantly from an average of 38.92 ± 3.20 SD (range 33–47°) preoperatively to an average of 3.27 ± 1.17° SD (range 2–6°) postoperatively and to 3.35 ± 1.16 SD (range 2–6°) at the last follow-up (Table 2).

At the last follow-up, all 24 patients were neurologically assessed. There were three ASIA B patients; of them one patient improved to ASIA D and two patients to ASIA E. There were three ASIA C patients; of them, two patients improved to ASIA D and one patient improved to ASIA E. The two patients who were classified as ASIA D were neurologically normal at the final follow-up. Hence, all patients who were less than ASIA E had improvement of at least one grade of ASIA score. At the last follow-up, 21 patients with ASIA E grade underwent the ODI functional evaluation. The functional disorder index mean score was significantly improved from 52.83 ± 11.87 (40–80) preoperatively to 14.30 ± 3.36 (9–22%) postoperatively (P < 0.001) (Table 3).

All patients showed significant pain reduction postoperatively (P < 0.001). Preoperatively, most of the patients were graded P4 (17 patients). One patient was graded P3 and five patients as P5. Postoperatively, most of the patients were of grade P1 (17 patients), four patients were P2, and two patients were P3 (Table 3).

Dural adhesions into the overlying lamina were evident in three patients (12.5%). The dura was dissected and freed completely to avoid tethering of the dura during correction. There was no patient with neurological deterioration. One patient developed superficial wound infection and was treated with antibiotics without recurrence. No patient required ICU admission, and there were no postoperative mortality cases.

At the last follow-up, there was no patient with deep infection, hardware failure, or progression of kyphosis. Fusion was evident in all cases with insignificant loss of correction at the final follow-up.

Case presentation

A 25-year-old male patient with burst fracture of L2 was treated with short-segment posterior fixation that resulted in failure of implant and development of PTK. The patient presented with low back pain 7 months after the first operation. The patient was treated with posterior modified PSOS, interbody cage, and posterior instrumentation with good correction without loss of correction at the final follow-up and solid fusion (Figs 2–4).

Discussion

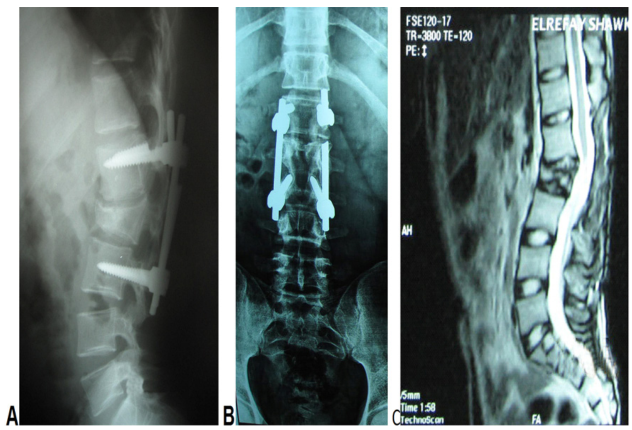
Although PTK is defined as a painful kyphotic angulation that can occur anywhere in the spine, asymptomatic PTK can also exist. Deformity of 30° or more has an

Table 2 Radiological results

Preoperative angles	Preoperative	Postoperative	Last follow-up
LKA	36.54 ± 3.23	1.15 ± 4.43	1.27 ± 4.38
SI	38.92 ± 3.20	3.27 ± 1.17	3.35 ± 1.16

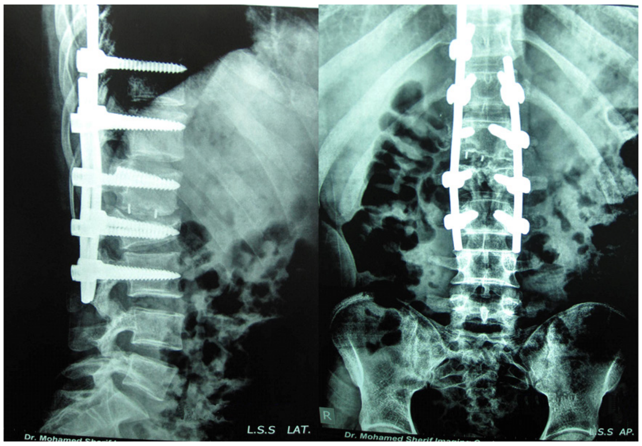
LKA, local kyphosis angle; SI, sagittal index.

Figure 2



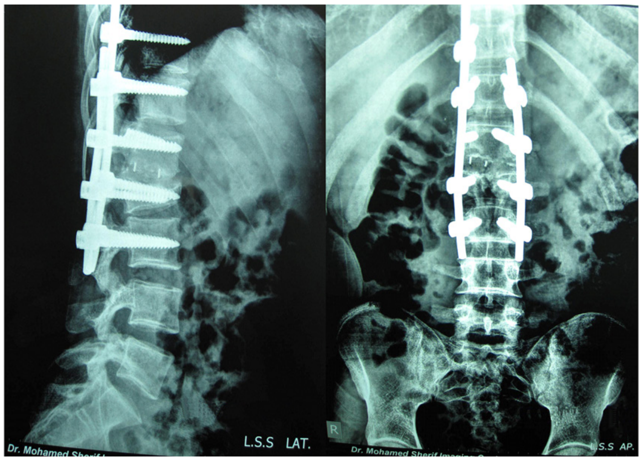
Preoperative plain radiograph showing post-traumatic kyphosis at L2 fixed by short monosegmental posterior instrumentation with implant failure: (a) lateral view, (b) anterior–posterior view. (c) Preoperative MRI showing marked wedging of the L2 and angular kyphosis with stretching of the cord over the kyphos.

Figure 3



Immediate postoperative anterior–posterior and lateral view showing correction of the kyphos and double segmental fixation above and monosegmental fixation below the wedged vertebra together with inclusion of the affected wedged vertebra and cage and bone graft in position.

Figure 4



AP and lateral radiographs taken at the last follow-up showing good alignment and bony fusion without change in the postoperative kyphosis angle and no implant failure.

Table 3 Functional results

Disability index	Preoperative (*n* = 24) [*n* (%)]	Postoperative (*n* = 24) [*n* (%)]	*P* value
ODI	52.85 ± 11.87	14.30 ± 3.36	<0.001
Pain scale			
P1	0 (0)	17 (70.8)	<0.001
P2	0 (0)	5 (20.8)	
P3	4 (16.7)	2 (8.3)	
P4	15 (62.5)	0 (0)	
P5	5 (20.8)	0 (0)	
Work scale			
W1	0 (0)	16 (66.7)	<0.001
W2	0 (0)	6 (25)	
W3	4 (16.7)	2 (8.3)	
W4	14 (58.3)	0 (0)	
W5	6 (25)	0 (0)	

ODI, Oswestry disability index.

increased risk of chronic pain or progression [11]. Surgical correction of PTK should be considered in patients presenting with a LKA of more than 20° with poor functional tolerance, severe or increasing back pain and disability, angular deformity, nonunion, focal instability, breakdown of levels above or below the deformity, radiculopathy, and/or increasing neurologic deficit. Adjacent painful compensatory deformity such as lumbar hyperlordosis, thoracic hypokyphosis, or lordosis is a further argument for surgery [3].

PTK is the most common form of type I (focal) sagittal imbalance that is associated with normal global alignment, and its treatment is different from that of type II (global) sagittal imbalance. The site of osteotomy is at the apex of deformity [3]. The primary aim of surgical treatment for PTK sharp angular kyphosis is to achieve thorough decompression of the neural elements, removal of all bone fragments from the posterior vertebral body impinging on the cord, correction of angular deformity, and stabilization of the spine for bony fusion. Anterior correction of deformity is often difficult, often hindered by the posterior structures [12,13], and is associated with higher pseudarthrosis rate and loss of correction. Anterior instrumentation alone is controversial and not sufficient for stabilization of the spine, especially in osteoporotic bone. Kostuik and Matsusaki [14] in their study on the anterior-only procedures found that only one-half of patients went into solid bony fusion. El-Sharkawi MM *et al.* (2011) reported significant loss of correction in the anterior-only (ACP) group and insignificant loss of correction in the posterior-only PSOS group. Malcom *et al.* [15] reported 40% complication rate in the anterior-only approach, including pseudarthrosis and loss of correction, and recommended combined anterior and posterior approaches for post-traumatic deformity. Similar conclusions have been made by many other authors [1,16]. There is consensus that both the anterior and posterior factors should be addressed for sufficient restoration of sagittal alignment to obtain solid bony fusion in rigid kyphosis, and this could be achieved in a single posterior or combined approaches.

The posterior approach is more familiar to most spine surgeons. Decompression is easier because the apex of deformity is more accessible and easily approached posteriorly and the neural elements and the wedge fragment compressing it are identified under direct vision and protected early in the procedure. Correction of deformity is facilitated by excising the posterior elements, especially the fused or ankylosed facets, making correction easier [13]. Posterior fixation allows better correction, provides stronger fixation for solid bony fusion, and can be extended over many segments as required [12], especially in junctional areas.

Although one-stage posterior shortening osteotomy procedure is technically demanding, it has a number of reported advantages over combined procedures. These include shorter operative time, less intraoperative bleeding, diminished postoperative morbidity, which is especially important in patients with less than optimal pulmonary function, more reliable alignment, and solid bony fusion [17,18]. The ability to work simultaneously anteriorly and posteriorly at the same time through a single approach for anterior reconstruction and graft adjustment is another advantage. Combined anteroposterior surgery is associated with a high perioperative complication rate, and its use should be limited to revision and pseudarthrosis cases and fusions across the lumbosacral junction [18].

Posterior osteotomies that hinge on the posterior longitudinal ligament or on the cord cause opening of the anterior column (i.e. SPOS). Posterior closed wedge osteotomies hinge on the anterior longitudinal ligament and gain correction without distraction of the anterior column (e.g. PSOS and modified PSOS). In closed-open wedge osteotomy, the first 30–40° of correction is achieved with the closed wedge hinged on the anterior longitudinal ligament. Thereafter, the hinge is shifted posteriorly and the remainder of correction is achieved with the open wedge technique to avoid excessive shortening of the spine and kinking of the cord. This open wedge technique can be achieved by inserting a strut autograft or vertebral spacer into the anterior intervertebral gap, by careful disruption of the anterior hinge (either bone or ligament), by means of total vertebretomy to open up the anterior column, or using a three-stage, posterior–anterior–posterior surgery.

Smith-Peterson [19] osteotomy (SPOS) is only a posterior column chevron osteotomy that shortens the posterior column and lengthens the anterior column through a mobile disc space. This leads to further destabilization of the spine, thereby requiring rigid posterior fixation or combination with an anterior column support to prevent failure before fusion occurs. This osteotomy may be effective in long-segment kyphotic deformity as in ankylosing spondylitis, but not in short-segment or angular kyphotic deformity. The average correction obtained with a single SPOS is 10–15°, with expected 1° of correction for each millimeter of posterior resected bone [19].

A posterior closing wedge osteotomy such as PSOS is a three-column osteotomy. It results in shortened posterior column, avoiding tension on the cord, and provides bone-to-bone contact in the anterior column for good bone healing. However, it is limited by the anatomy of the cord as excessive shortening will produce kinking and bucking of the dura, which may affect the cord blood supply and CSF circulation and may require duraplasty. It is also limited by the size of the wedge and the angle of correction. It is most suitable for correction of angles less than 35°, as reported in most studies [4,20].

In case of PTK, the vertebral body is usually deficient and triangular in shape. The upper endplate, which is the most commonly affected part in burst fractures, is not smooth and has an irregular surface; the disc penetrates inside and it is difficult and impractical to perform a transvertebral wedge osteotomy as the proximal fragment of the osteotomy will be small and deficient and the osteotomy will pass into the disc space. The posterior elements show spontaneous facet fusion that prevents or limits anterior correction and needs excision during correction. The disc is disrupted, degenerated, shows signs of instability, is a source of nonunion and progression of deformity, and is a source of back pain. Therefore, the technique of PSOS should be modified to include resection of the upper disc to ensure good bony contact and healing and to prevent failure. Using the disc as a part of the resected wedge increases the operative space, the size of the resected wedge, and the angle of correction without excessive bone excision. This minimizes the bleeding, makes the technique more easier and simple, and saves most of the pedicle that can accommodate unilateral or bilateral screws in the wedged body adding additional fixation points and thereby saving more distal mobile segments and avoiding translation of the affected body that may lead to impingement on the neurological structures. Excising the degenerated disc material also prevents correction loss, achieves good bony contact for union, and decreases the rate of pseudarthrosis, loss of correction, and implant failure. Using a spacer in the anterior intervertebral defect supports the load-sharing anterior column, thus adding to the stability and allowing early mobilization and rehabilitation. Moreover, it increases the angle of correction as it acts as a pivot for closing the posterior wedge region with instrumentation without excessive shortening of the cord. The angle of correction is the sum of the size of the posterior closing wedge and the height of the spacer. Chou-Kuan *et al.* [21] on studying the relation between the height of the osteotomy and the angle of correction showed that the angle of correction in the closing wedge osteotomy was 2.5°/1 mm and that this increased to 6.2°/1 mm in the height of osteotomy by inserting the graft or cage anteriorly. They concluded that, for safety reasons, the angle of correction in the closing wedge should be less than 45° and the height of osteotomy should be less than 20 mm, otherwise severe neural injury will occur. Using a spacer also prevents excessive compression and narrowing of the intervertebral foramina and nerve root entrapment, especially in the lumbar spine.

We believe that correction using the modified PSOS is more anatomical as the apex of deformity in post-traumatic cases is at the level of the disc, and the upper endplate and correction should be at the level of the apex to have maximum degree of correction and avoid translation of the spine to avoid impingement on the cord, thus making the correction more safe. The technique is also more versatile as we start with disc excision and then the bone is excised as required based on the angle of correction and flexibility of deformity. This decreases the amount of blood loss and extent of the procedure. Closure of the osteotomy is easier because it passes through the mobile disc space. This avoids excessive lateral bone excision from the pedicle or the vertebral body. Because of this little bone excision laterally, the vertebral body may falsely appear somewhat triangular in the postoperative x-ray film.

In this study, using the modified PSOS technique we achieved good and safe correction with insignificant loss of correction at the final follow-up and no implant failure with good functional outcome as evidenced by significant improvement in the pain scale and ODI score. Most of the patients returned to the previous level of activity. In this series the maximum angle corrected using this technique was 40°, but we believe that the angle of correction can be increased by increasing the size of the spacer using expandable cages. The operative time, intraoperative blood loss, and postoperative morbidity were significantly lower compared with those reported for the combined anterior–posterior approaches in other studies. Suk *et al.* [17] in their comparative study between combined and anteroposterior approaches reported a mean operative time and blood loss of 351 min (range 200–580 min) and 2892 ml (range 900–5850 ml), respectively, in the combined approach group and 215.7 ± 50.3 min (range 160–330 min) and 1930 ml (range 750–375 ml), respectively, in the posterior-only group. Wiggins *et al.* [22] in their comparative study between the posterior group (GI) and the anterior or combined group (GII) in cases with different pathology reported that the estimated blood loss and operative time were 2276 ml and 420 min, respectively, in GI and 2442 ml and 384 min, respectively, in GII due to larger exposure and multilevel instrumentation. Kawahara *et al.* [12] reported that the estimated blood loss and operative time for the closing-opening wedge osteotomy group was 2386 ml (range 1300–3560 ml) and 9.6 h (range 8–11.5 h), respectively. In this series, the average amount of blood loss and operative time were lower. This can be explained by the absence of tumor cases as reported in some studies and by the limited approach, limited bone excision, and limited extent of fusion.

Conclusion

Excising the disc and using it as part of the resected wedge during correction of PTK using the modified PSOS is a safe, logical, and more anatomical strategy that achieves good degree of angle correction at the apex level and maintained correction with lower operative morbidity. It is associated with good clinical and radiological outcomes.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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