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RESEARCH ARTICLE

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The Outcome of Pedicle Subtraction Osteotomy (PSO) For the Correction of Post-Traumatic and Post-Tubercular Kyphotic Deformity

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ABSTRACT

Introduction: Pedicle subtraction osteotomy (PSO) is one of the well-established and well-known techniques for kyphosis correction.

Objective: Objective of our study is to analyze the clinical and radiological outcomes of PSO in terms of VAS to access the pain relief, ODI to assess the functional outcome, and the ASIA impairment scale for pre-operative and postoperative assessment of neurology. The per-operative and postoperative complications related to surgery, access radiological correction of deformity in terms of kyphosis angle, and postoperative fusion status.

Method: Ten patients with dorso-lumbar kyphosis (5 post-tubercular and 5 post-traumatic) were followed up for an average of 2 years after PSO. They were assessed prospectively for clinico-radiological and functional outcomes. The neurological deficit, cosmetic deformity & back pain were the major complaints among the study population.

Result: For the post-tubercular kyphosis group, the mean pre-operative kyphosis angle was 67.5°±10.4° and 14.9°±6.1° postoperatively, with significant improvement ($p<0.001$) at a mean follow-up of 24 months. The mean ODI improved from 44.1±12.4 pre-operatively to 21.1±7.1 at the latest follow-up. Pre-operative VAS was 8.9±2.5, with a significant improvement of 1.5±1 in the final follow-up. For the post-traumatic kyphosis group, the mean pre-operative kyphosis angle was 33.7°±4.5° and 3.8°±3.4° postoperatively, with a significant improvement ($p<0.001$). Here the mean ODI improved from 37±2.5 pre-operatively to 6.0±1.9 at the latest follow-up. Pre-operative VAS was 8.4±1 with a significant improvement of 1.25±1 in the last postoperative follow-up. Fusion was achieved in all cases. Transient neurological deficit was found in 1 patient who became normal after 3 months. All patients had ASIA grade "E" at last follow-up. There were no significant intraoperative major complications in this group either, except a few minor complications.

Conclusion: A greater degree of kyphotic correction (>40°) can be obtained with a single pedicle subtraction osteotomy at the dorso-lumbar level with minimal neurological complications.

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Introduction

Kyphosis is a typical sequel of post tubercular and neglected or inadequately managed thoracolumbar fractures. Post-traumatic kyphosis may become progressive as the line of gravity shifts forward and as the posterior erector muscles weaken [1]. Patients with kyphotic deformities are at an increased risk of chronic pain in their kyphotic region and may occasionally develop progressive neurologic deficits [2-4]. Furthermore, compensatory hyperextension of the lower lumbar spine has been linked to a higher incidence of low-back pain, degenerative facet arthritis,

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and painful spondylolysis [2,4]. An abnormal kyphotic spine can result in a positive sagittal imbalance that may have deleterious effects on the overall biomechanics of the spinal column. Loss of sagittal balance can cause intractable backaches due to abnormal posture and can cause lower limb muscle fatigue and the inability to maintain a horizontal gaze. Kyphosis correction in the spine is a massive undertaking and requires careful preoperative clinical, radiological evaluation and immense technical expertise on the surgical team.

Since first being described by Thomasen in 1985, pedicle subtraction osteotomy (PSO) has been increasingly used for the surgical correction of fixed sagittal plane deformity resulting from congenital posttraumatic, metabolic, infectious, and neoplastic disorders [5,6]. Pedicle subtraction osteotomy is known to be associated with significant perioperative morbidity [7-11]. However, recent advances in surgical technique, improved anesthetic management, and intraoperative neurological monitoring may reduce the rate of neurological morbidity [11]. In this article, we evaluated the clinical and radiological outcomes of our 10 cases.

Several years ago, pedicle subtraction osteotomy (PSO) was introduced to correct sagittal imbalance as an alternative method with favorable outcomes [1, 12-17]. Buchowski et al. recently reviewed the literature concerning post-traumatic kyphosis and recommended using PSO in cases associated with average sagittal balance and sharp angular deformity [18]. PSO can be used at the dorsal level at the expense of increased neurological complications. PSO is most useful for deformations with an apex in the lumbar spine [19]. We present our experience with the PSO for surgical correction of dorso-lumbar kyphosis. We aimed to correct the deformity and relieve back pain by restoring the rmal spinal curvatures and achieving a solid fusion.

The aim of our study is to compare the clinical and radiological outcomes of PSO for correcting post-tubercular and post-traumatic kyphosis of the thoracolumbar spine.

Material and Methods

From January 2014 to December 2020, we conducted a retrospective analytical study of patients undergoing thoracolumbar pedicle subtraction osteotomy with ten patients in the spine unit of the Orthopedic Surgery department of Bangabandhu Sheik Mujib Medical University, and other private hospital in Dhaka, Bangladesh, from January to December.

PSO was done for post-tubercular and malunited thoracolumbar fractures to correct the kyphotic deformity. The follow-up period ranges from 1 year to 2 years (an average of 18 months). Within this follow-up period, we have assessed the patients clinically, functionally, and radiologically. All patients were evaluated pre and post-operatively by, Oswestry Disability Index (ODI) for functional outcome, visual analogue score (VAS) to access the relief of back pain and leg pain, American Spinal Injury Association (ASIA) impairment scale for pre-operative and post-operative assessment of neurology, Radiological correction of deformity in terms of kyphosis angle, post-operative fusion status. The per-operative and post-operative complication related to surgery, For statistical analysis, IBM-SPSSS V26 software was used.

Selection of patients for surgery

Inclusion criteria

Patients with post-tubercular and malunited thoracolumbar fractures with kyphotic deformity who had back pain, neurological deficit, and restriction of movement not responding to conservative treatment.

Exclusion criteria

Patients with kyphosis due to congenital, metabolic, pyogenic infections, and neoplastic disorders are excluded. Severe comorbidities and infection at the local incision site were also excluded.

Operative technique

The patient is prone on two parallel pillows on a radiolucent table after general anesthesia ensure the abdomen hangs free. After proper cleaning, painting, and draping of the operative area, a posterior midline incision was made, extending from above and below the apex of the deformity. The skin and subcutaneous tissue were cut in a single line, and the deep fascia and supra spinous ligaments were cut in the same plane by diathermy. Then the paraspinal muscle retracted subperiosteally up to the tip of the transverse processes bilaterally. Attention was paid to performing meticulous exposure of all posterior bony structures: lamina, isthmus, facet joint, and transverse processes. After exposure of the thoracolumbar spine, paraspinal muscle separation is maintained by the retractor until the closure of the osteotomy, ensuring the paraspinal muscle will not be entrapped during removal of the lateral vertebral body wall during the osteotomy. Then the space was identified under C-ARM guidance.

Implantation of poly-axial pedicle screws was done at least two levels above and two levels below the PSO level.

After resection of the base of the transverse processes of the dorso-lumbar vertebrae, separation of the paravertebral muscles was done, followed by resection of the inferior facets of the cephalad vertebra, resection of the isthmus, and superior and inferior facets of the index vertebra. The lamina of the osteotomized vertebra is kept in connection with the ligamentum flavum for a good bony continuum with the posterior elements after the closure of the osteotomy. Pedicles are then resected using a specific bone osteotome. Then cancellous bone is progressively removed through each pedicle without removing any part of the adjacent disks. In the case of the hard bones inside the vertebral body (mainly in the post-traumatic kyphosis group), drilling with progressive decrease in size seemed efficient and safe for this step of the procedure. Then lateral cortical bone is removed in a wedge-shaped manner, avoiding injury to segmental vessels along the lateral wall of the vertebral body. The posterior wall is finally resected by a Kerrison rongeur under the dural sac, which is gently pushed on the opposite side.

Closure of the PSO is performed by combination of patient repositioning on the operative table (extension of the hip joints and elevation of the upper part of the trunk) and gradual and gentle compression between the pedicle screw heads. Excessive resistance during PSO closure is highly suggestive of insufficient bony resection and persistence of cortical bridges, especially on the lateral wall of the vertebral body. Excessive stress on pedicle screws should be avoided in order to reduce the risk of

mechanical failure of the hardware. PSO closure was done with meticulous attention to prevent nerve roots or dural sac entrapment. Compression of neurological structures was absolutely verified at this stage. Autografts were applied to the surface of the posterior bony elements along all the instrumented spines. We put gel foam over the open dura. Proper hemostasis was ensured in every step of surgery. The wound was closed in the anatomical layer by absorbable 1/0 cutting body vicryl and skin by skin stapler, keeping a drain in situ.

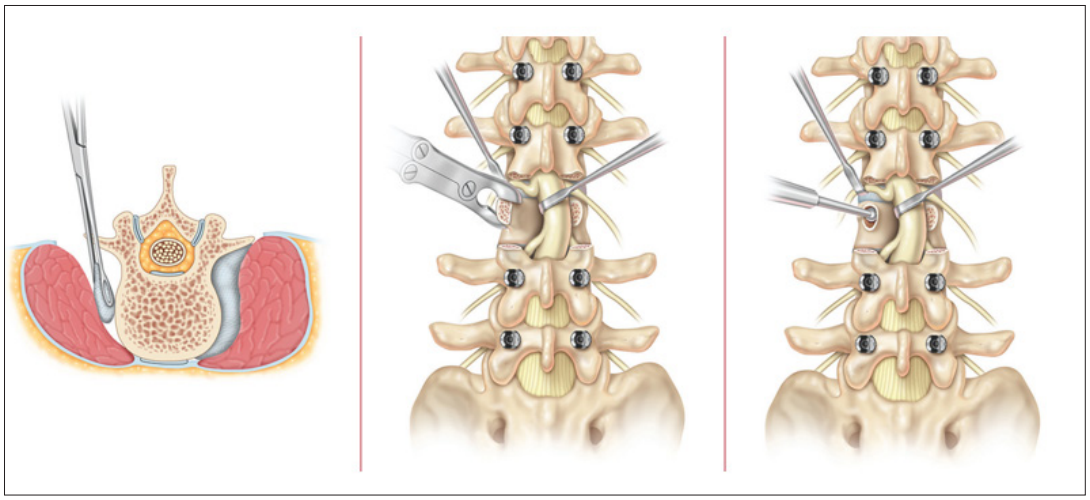

Figure 1: The psoas muscle is dissected away from the lateral aspect of the vertebral body; removal of the posterior elements of the spine exposes the pedicles, which are then removed with a rongeur or drill. The removal of the pedicle allows access to the vertebral body, which is de-cancellated with a pedicle probe and drill to create a wedge resection. Praveen et al.

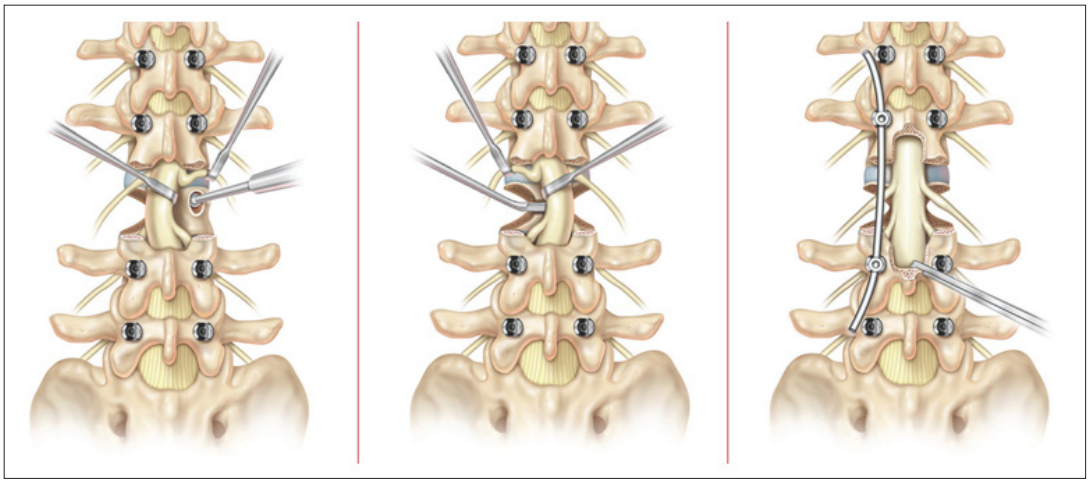

Figure 2: After de-cancellation, the portion of the vertebral body underlying the anterior spinal canal is removed by collapsing this bone into the de-cancellated cavity with a down-facing curette. Then a temporary rod is placed to secure the spine before osteotomy closure. The posterior decompression may need to be extended to cephalad or caudad to remove bone from the lamina above and below the osteotomy level to avoid kinking of the dura during osteotomy closure. Praveen et al.

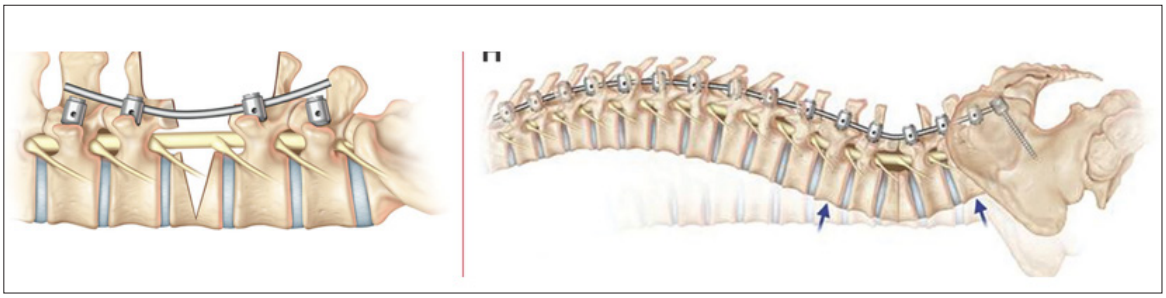

Figure 3: The osteotomy is closed, and the new position of the spine is secured with permanent anatomical pre-contoured rods. Praveen et al.

Results

The retrospective analytical study includes 10 patients who fulfilled the inclusion criteria and were operated by PSO for post-tubercular kyphosis and post-traumatic kyphosis deformity. All patients were followed up from 2 years to 4 years (at least 24 months) postoperatively.

Table 1: Summary of demographics, comorbidities, surgical data

Patient	Age	Sex	Comorbidities?	Indication	No. of deformity Level	Level of PSO
1	34	Male	No	Post-tubercular kyphosis	D11- D12	D12
2	28	Female	No	Post-tubercular kyphosis	D12- L1	L1
3	37	Male	Yes	Post-tubercular kyphosis	D12-L1	L1
4	29	Male	Yes	Post-tubercular kyphosis	L1	L1
5	30	Female	No	Post-tubercular kyphosis	D11-L1	D12
6	52	Male	No	Posttraumatic kyphosis	D12	D12
7	44	Male	No	Posttraumatic kyphosis	D12	D12
8	60	Male	No	Posttraumatic kyphosis	L1	L1
9	58	Male	No	Posttraumatic kyphosis	L1	L1
10	46	Male	No	Posttraumatic kyphosis	L1	L1

The mean age of the post-tuberculosis group was 31.6 ± 3.4 years and the post-traumatic kyphosis group, 52 ± 6.3 years. 3 (60%) patients were male, 2 (40%) patients were female in the post-tuberculosis group, and 5 (100%) were male in the post-traumatic kyphosis group.

Table 2: Correction of kyphosis angle, VAS and ODI by Primary Diagnosis

	Mean kyphosis angle		Mean VAS		Mean ODI	
Post-tubercular kyphosis group	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op
	67.5° ± 10.4°	14.9° ± 6.1°	8.9 ± 2.5	1.5 ± 1	44.1 ± 12.4	21.1 ± 7.1
Posttraumatic kyphosis group	33.7° ± 4.5°	3.8° ± 3.4°	8.4 ± 1	1.25 ± 1	37 ± 2.5	60 ± 1.9

Table 3: Assessment of neurology, according to "The ASIA impairment scale" (34)

Group	Pre-operative					At last follow-up				
ASIA Grade	A	B	C	D	E	A	B	C	D	E
Post-tubercular kyphosis group. (5 patients)	0	3	0	2	0	0	0	0	0	5
Post-traumatic kyphosis group. (5 patients)	0	0	2	3	0	0	0	0	0	5

Table 4: Summary of complications

	Intraoperative				Postoperative			
	Dura injury	Cord or nerve root injury	visceral or vascular injury	Coagulo-pathy	Neurological deficit	Superficial/ deep infection	pseudoarthrosis	Hardware failure
Post-tubercular kyphosis group. (5 patients)	1	No	No	No	1(Transient radicular deficit.)	No	No	No
Post-traumatic kyphosis group. (5 patients)	1	No	No	No	No	1(superficial wound infection.)	No	No

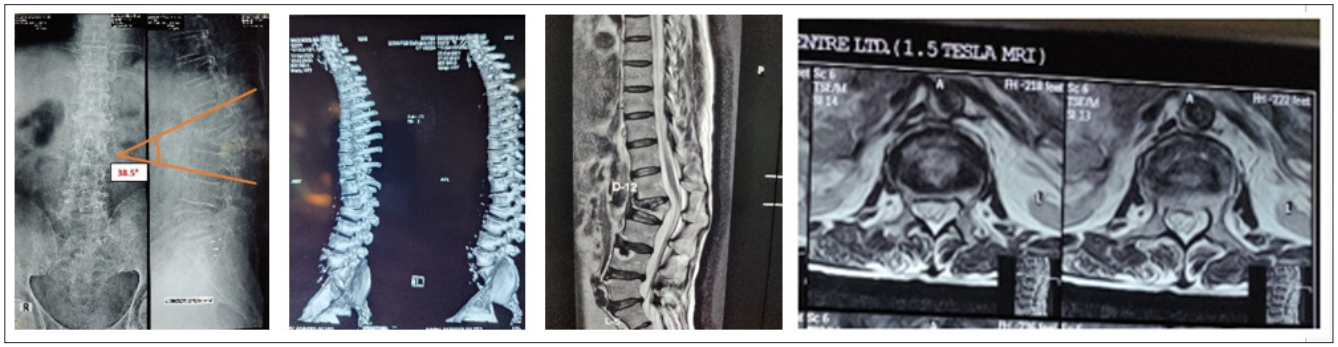

Figure 1: preoperative x-ray dorso-lumbar spine showing kyphosis angle of 38.5 degrees, 3D CT scan and screening MRI of a 50-year-old male patient with a history of fall from height and Brust fracture of L1.

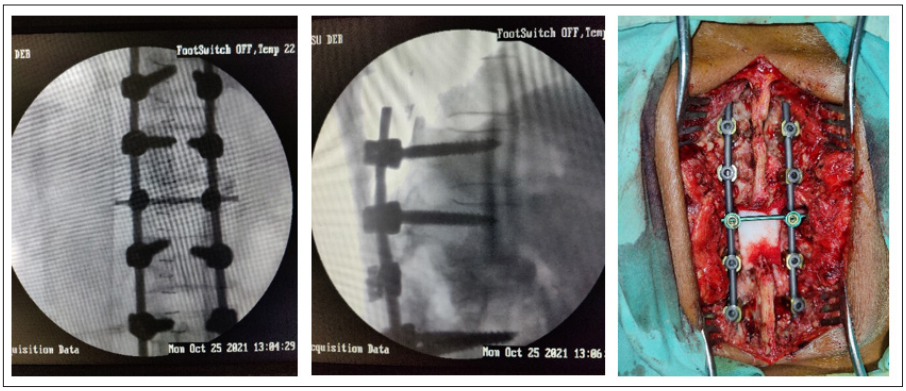

Figure 2: PSO of L1 done, correction of kyphosis made by inserting pedicle screws at D11, D12 above and L2, L3 below, connected by anatomically contoured rods and connector.

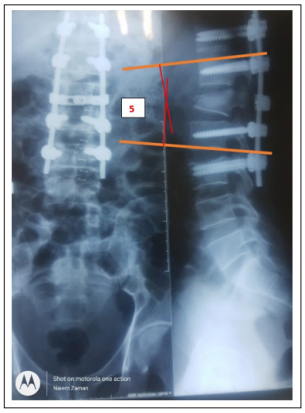

Figure 3: postoperative x-ray. After PSO, the kyphosis angle was found to be only 5 degrees

Discussion

The mean age of the post-tuberculosis group in our study found 31.6 ± 3.4 years, and the post-traumatic kyphosis group 52 ± 6.3 years. Kim et al., in their study of multiple etiology, shown mean 37.6 (25–61) and 62.3 (25–75) years in post-tuberculosis and post-traumatic kyphosis group respectively [20]. In his study, male-female ratio was 1:1 and 6:11 in post-tuberculosis and post-traumatic kyphosis groups, respectively. In our study, we found male-female ratio 3:2 in post-tuberculosis but 5:0 in post-traumatic kyphosis group.

In their study, Barrey et al. found a significant outcome after PSO surgery [21]. The VAS improved from 7.5 ± 2 pre-operatively to 3.2 ± 2.5 at 1 year, we found Pre-operative Visual Analogue Score (VAS) 8.9 ± 2.5, with a significant improvement of 1.5 ± 1 in the last post-operative follow-up which is comparable.

Kalra et al. studied the healed tuberculosis of the spine and the resultant kyphosis of 15 patients [22]. PSO was performed by wedge resection of the vertebra using a transpedicular approach. After a mean follow-up period (26.8 months), the outcome was good, with an improvement in the mean Oswestry Disability Index from 56.26 (48 to 62) pre-operatively to 11.2 post-operatively. In our study, ODI improved significantly from pre-operative 44.1 ± 12.4 to 21.1 ± 7.1 at final follow-upin the post-tuberculosis group of patients.

The mean pre-operative kyphosis from study of Kalra et al. was 58.8 (34 to 100), with a significant improvement in immediate post-operative kyphosis of 13.7 (0 to 40) [22]. In our study of post-tubercular kyphosis group, pre-operative kyphosis angle improved from 67.5° ± 10.4° to 14.9° ± 6.1°, which is also very much significant.

Yong-Ming et al. in his study of pedicle subtraction osteotomy for chronic, post-traumatic thoracolumbar kyphosis of 14 patients, the pre-operative ASIA impairment scale was B in 3 patients, 2 of whom were restored to ASIA C [23]. For the 3 patients who had a pre-operative ASIA scale of C, 2 were restored to ASIA D. Of the 5 patients with a pre-operative ASIA scale of D, four were restored to ASIA E. No changes were seen in the patients with pre-operative ASIA E. In our study, 2 patients had an ASIA scale of B and 3 patients had an ASIA scale D pre-operatively in the post-traumatic kyphosis group. All become ASIA scale E at final follow-up. In post-tubercular kyphosis group, we found ASIA scale B in 3 patients and ASIA scale D in 2 patients, and they also become ASIA scale E at final follow-up, which indicates a highly significant outcome.

Post-traumatic kyphosis group of our study, VAS improved from 8.4 ± 1 pre-operatively to 1.25 ± 1 in post-operative period. By Yong-Ming et al. in his study of correction of post-traumatic thoracolumbar kyphosis using pedicle subtraction osteotomy VAS improved from a pre-operative mean 6.7 (5.0–8.0) to an average 2.0 (0–3.0) at final follow-up which is comparable with our study [23].

In Kim et al. in their study of PSO for multiple etiologies, in the post-traumatic kyphosis group, ODI improved from 44.7 ± 3.2 pre-operatively to 23.3 ± 2.6 post-operatively [20]. In the post-traumatic kyphosis group of our study, ODI improved from 37 ± 2.5 pre-operatively to 6.0 ± 1.9 at the final post-operative follow-up. Likewise, the mean ODI score showed a significant decrease from 38.1 ± 3.5 to 6.2 ± 1.9 in the PSO group from the study of El-Sharkawi et al [24].

Chou et al. in their study of PSO for the correction of post-traumatic thoracolumbar kyphosis, the kyphosis angle in the thoracolumbar junction was corrected from 40 degrees to 10 degrees with overall sagittal balance improvement [25]. In our study, the kyphosis angle was corrected from 33.7° ± 4.5° to 3.8° ± 3.4°, which denotes a significant outcome.

Complications in PSO surgery commonly refer to pulling out of screws, recurrence of deformity requiring revision, transient lower limb paranesthesia, aortic injury, pseudarthrosis, dural tear, cord and nerve root injury and infection. There was a per-operative dura injury, 1 in the post-tubercular and 1 in the post-traumatic group. One patient in the post-tubercular group developed a transient radicular deficit, which recovered after three months post-operatively. One patient had a superficial wound infection in the post-traumatic group, which was cured by antibiotics according to culture and sensitivity with regular dressing. No, major complication was detected in our study. Kalra et al. found few peri-operative complications and were completely satisfied with their overall outcome [22]. Yong-Ming et al. operated on 19 patients by PSO; there was dural leakage in 1 and wound infection in 1 patient, which recovered well by conservative treatment [23]. Kim et al., out of his 140patient treated by PSO, 15 developed reversible complications like transient radiculopathy and 3 irreversible complications [20].

PSO showed maintenance of deformity correction and solid fusion in the study of El-Sharkawi et al., solid fusion was achieved in all 19 patients by the study of Yong-Ming et al., and Gavaskar et al., by PSO surgery. achieved fusion at the osteotomy site in all 52 patients for rigid kyphosis of the dorso-lumbar spine. Radiological union at the osteotomy site was achieved in all patients in both of our study group [24,23-26].

Conclusion

Sagittal plane imbalance is very disabling for patients and typically results in significant back pain, limitation in mobility, and a poor quality of life [27, 28, 29]. The degree of correction can be predicted by trigonometric means [30, 31]. Despite complications, patient satisfaction after PSO has been reported to be greater than 90% [32]. The long-term benefits of restoring sagittal balance with PSO have been documented in dorso-lumbar kyphosis [33-36].

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