"Pedicle Subtraction Osteotomy for the Correction of post-traumatic kyphotic deformity in the Thoraco-lumbar Region: A Clinical Outcome Study"

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Background: Kyphotic deformity occurs due to congenital defects, chronic infection, systemic inflammatory diseases and post-traumatic conditions of the spine. Pathological changes in post- traumatic kyphosis include muscle or disc degeneration, canal or neural foramen compromise and local instability. Pain is caused and neurological impairment is present in a delayed condition (Xi et al. 2013). Pedicle subtraction osteotomy is a highly technical procedure that has gained popularity due to its reliable one-stage correction (Ahmed sleem, 2017). The posterior column and both pedicles were resected with wedges and a hinge made at the anterior cortex of the vertebral body (Roberson et al. 2005). Objective: To evaluate the outcome of Pedicle Subtraction Osteotomy (PSO) for post-traumatic kyphotic deformity. Materials & Methods: This prospective interventional study was carried out in the Department of Orthopaedic surgery, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka from January'2020 to July 2022. All post-traumatic kyphotic patients in the dorso-lumbar region, regardless of age and gender, were enrolled as a study sample during this period. Pedicle subtraction osteotomy (PSO) was used to treat all patients. Clinical and radiological outcomes were assessed post-operatively at 1, 3, 6 and 12 months. The outcome was evaluated using visual analog score (VAS), Bridwell criteria, Oswestry Disability Index (ODI) score, kyphotic angle assessment, Denis work scale and modified Macnab's criteria. Statistical analysis: Data was processed and analyzed using the software 'Statistical Package for Social Science' version 26.0. The paired t-test was used to analyze quantitative data and express it as mean and standard deviation. Using a chi-square test, qualitative data was analyzed and expressed in frequency and percentage. Result: A total number of 15 post-traumatic kyphotic patients at dorso-lumbar region were included, among whom 10 (66.67%) were male and 5 (33.33%) were female with male female ratio of 2:1. Mean age was 38.6±14.27 years (ranging from 16-62 years). The maximum number of patients (33.33%) were farmers, followed by day laborers (26.67%). Back pain, weakness in lower limbs and kyphosi

were present in all patients. Most of the pedicle subtraction osteotomy procedures were done at L1 (66.67%). VAS score improved significantly in post-operative follow up compared to pre- operative status ($p<0.001$). Per-operative complication was seen in 1 (6.67%) patient (dural tear). Post-operative complications were present in two patients, with one (6.67%) suffering from wound infection and another (6.67%) experiencing implant failure during the 10th month of her surgery. Total durtion of hospital stay mean was 16.67 days, ranged from 14-23 days. Radiological fusion was found in the majority of patients after 6 and 12 months of follow-up, with 73.33% and 93.33% respectively. A significant clinical outcome was indicated by the ODI score. The kyphotic angle improved satisfactorily after the operation. Overall improvement was excellent in the majority of patients. Conclusion: Pedicle Subtraction Osteotomy (PSO) can be considered as a safe and effective procedure for correction of post-traumatic kyphotic deformity.

INTRODUCTION

Kyphotic deformity occurs due to congenital abnormalities (hemi-vertebra, scoliosis), chronic infection (spinal tuberculosis), systemic inflammatory disease (ankylosing spondylitis) and post-traumatic conditions of the spine. Post-traumatic kyphosis may progress because of the shifting of gravity forward and weakness of posterior erector muscles (Roberson et al. 1985). Unstable thoraco-lumbar spine is potential for serious complications (Malcom et al. 2001). Patients with focal kyphotic deformity that is equal to or greater than 30° are more likely to experience chronic pain or neurological deficit (Wang et al. 2008). Patients with kyphotic deformities are more likely to experience chronic pain in their kyphotic region and progressive neurological deficits (Malcolm et al. 2001). The higher incidence of low-back pain, degenerative facet arthritis and painful spondylolysis is associated with compensatory hyper-extension of the lower lumbar spine (Oda et al. 1999).

About 50,000 individuals experience traumatic spine fractures every year. Early conservative or surgical treatment is frequently employed to heal most traumatic thoraco- lumbar fractures. Post-traumatic kyphosis develops due to inappropriate treatment methods or time delay (Xi et al. 2013). Pathological changes in post-traumatic kyphosis include muscle or disk degeneration, canal or neuro-foramen compromise and local instability. Patients with post-traumatic kyphosis present with varying symptoms including local muscle fatigue or pain, focal deformity and neurologic deficits. Post- traumatic kyphosis presents several challenges to the spine surgeon. Non-operative

modalities used in the treatment of post-traumatic kyphosis include pain medications, physical therapy and core muscle strengthening.

Kyphosis correction requires a massive undertaking, careful preoperative clinical, radiological evaluation and immense technical expertise in the surgical team. Five types of spinal osteotomies have been available. Approaches include anterior, posterior or combined anterior and posterior. Pedicle subtraction osteotomy (PSO) was developed to achieve significant correction of kyphosis and restoration of lordosis using a single stage posterior approach (Barrey et al. 2007). PSO was first described by Thomasen (1985) in patients with ankylosing spondylitis. This is performed by removing the posterior elements and both pedicles, decancelling the vertebral body and closing the osteotomy by hinged on the anterior cortex (Roberson et al. 2005).

PSO is a time demanding procedure, used for the surgical correction of fixed sagittal plane deformity resulting from congenital, post traumatic, metabolic, infectious and

neoplastic disorders with relieving back pain, restoring the normal spinal curvatures and achieving a solid fusion (Hyun et al. 2013). An average of 30° to 40° correction can be achieved with a one level PSO. It is a quite challenging procedure having perioperative morbidity (Jain et al. 2004). Common pitfalls of PSO are bleeding, neurological deficit, infection, pseudoarthrosis. Implant failure after PSO is common, most of these instrumental failures (89%) occur at the index level vertebra or in adjacent vertebrae (Bridwell et al. 2003).

Methods

This Prospective Interventional study was carried out in the Department of Orthopaedic surgery, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka from January'2020 to July 2022. Purposive sampling technique followed by inclusion and exclusion criteria.

Inclusion criteria:

- Both genders.
- Symptomatic post-tubercular thoraco-lumbar kyphosis.
- Progressive motor or sensory deficit.
- Positive radiological findings for kyphotic deformity.

Exclusion criteria:

- Spine malignancy.
- Previous spine surgery and concomitant instrumented spinal fusion.
- Kyphosis due to congenital and metabolic deformity.
- Pyogenic spine infection.
- Patients who were not medically fit for surgery.

Variables:

- ❖ Demographic
  - Age

- Gender
- Occupation

❖ Clinical variables

- Back pain with lower limb weakness/pain
- Kyphosis
- Gait abnormality
- Motor weakness
- Sensory disturbance

} of lower limbs

- Bowel and bladder involvement

❖ Surgical variables

- PSO level
- Peri-operative complications
- Duration of total hospital stay

Outcome variables:

- Visual analogue score (VAS) for assessment of pain
- Bridwell criteria for assessment of radiological bone fusion
- Oswestry Disability Index (ODI)
- Kyphotic angle assessment
- Denis Work Scale
- Modified Macnab's criteria

} for overall outcome

Investigations:

The following tests were carried out routinely in all patients as a measure of anesthetic fitness, to rule out co-morbid diseases and to support the diagnosis of disease.

❖ Blood

- Total and differential count of WBC
- Estimation of Hemoglobin and ESR
- CRP
- MT test
- Blood sugar
- Blood urea
- Serum creatinine
- HBsAg
- Anti HCV
- RAT for corona screening

❖ **ECG**

❖ **Echocardiograph**

❖ **Radiological investigations:**

- X-ray chest (P/A view)
- X-ray of dorso-lumbar spine (A/P & Lateral view)
- MRI of dorso-lumbar spine with screening of whole spine
- CT scan of dorso-lumbar spine with screening of whole spine

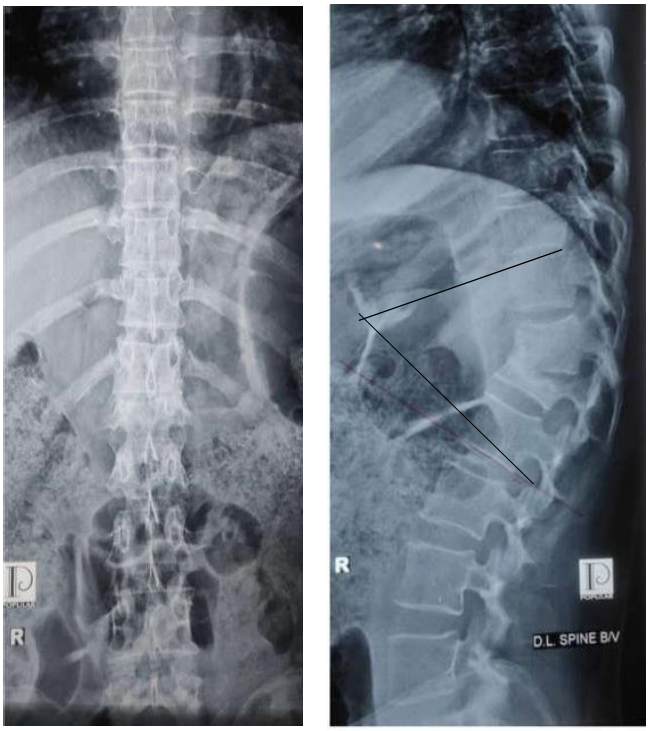

Figure 1: Pre-operative X-ray of D/L spine (A/P and lateral view) showing post tubercular kyphotic deformity at dorso lumbar region with kyphotic angle 35^0.

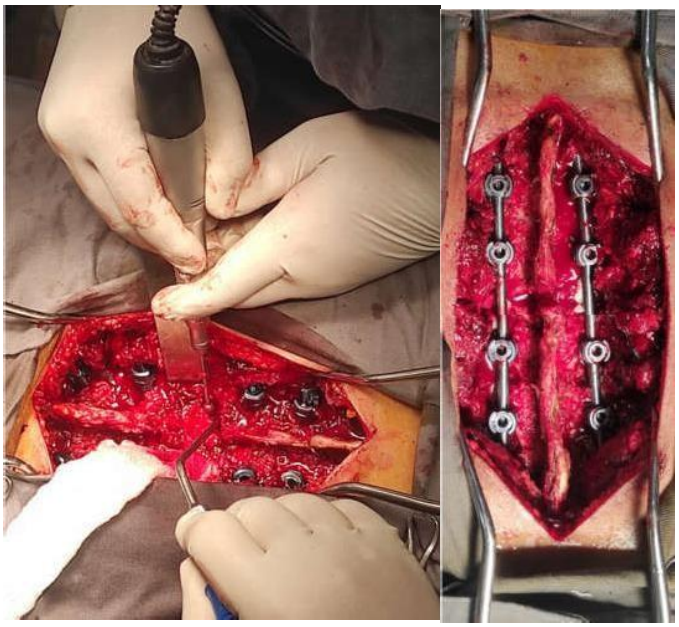

Figure 2: Per-operative picture showing; pedicle screws are inserted above and below the

PSO level followed by PSO with diamond bar

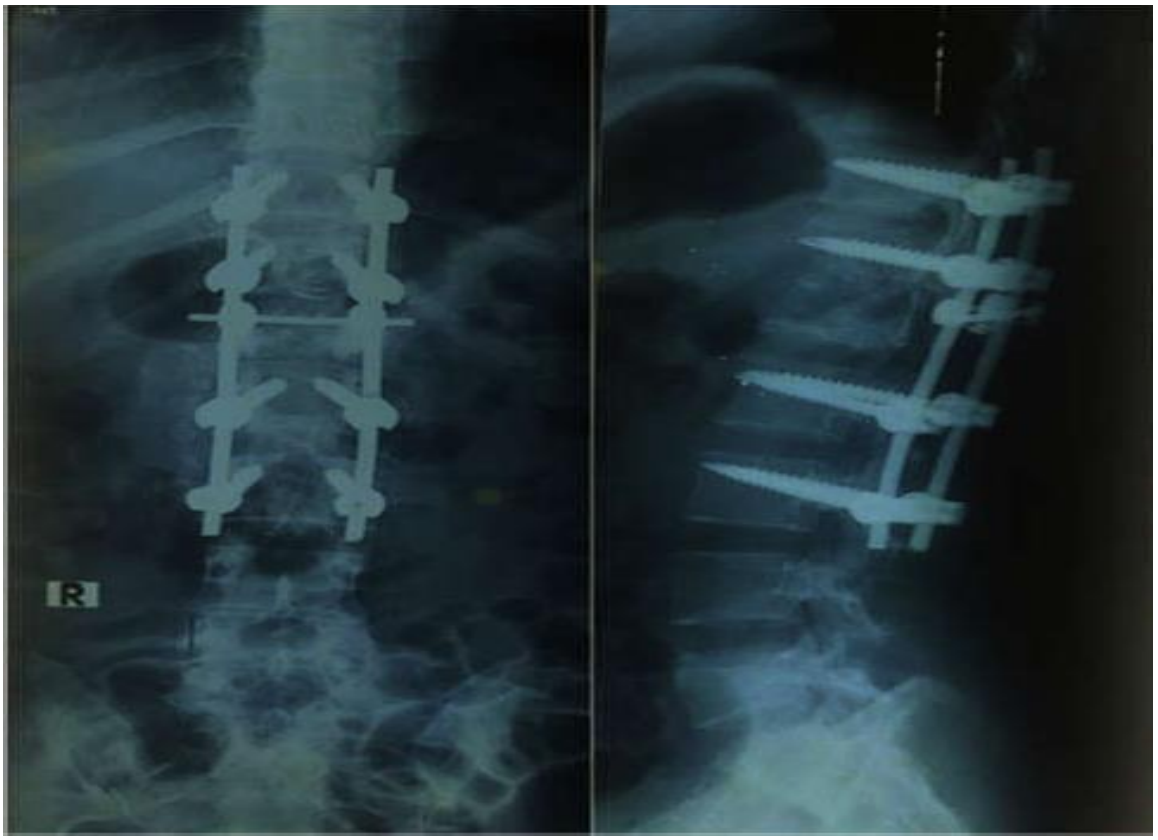

Figure 3: Post-operative (after 1 month of PSO) X-ray D/L spine AP and Lateral view showing proper implant position with correction of kyphosis.

RESULTS

Study population was 15 patients with post traumatic kyphotic deformity at dorso-lumbar spine who underwent pedicle subtraction osteotomy (PSO) with the fulfillment of all inclusion and exclusion criteria. All the data were compiled and sorted properly, analyzed statistically and placed in tables.

Age distribution of patients:

Total number of patients was 15 in this study. Age range was found between 16-62 years.

Distribution of study population according to age (Table I).

Table I: Age distribution of patients (n=15)

Age (years)	Frequency, n (%)	Mean ± SD
15-24	2 (13.33)	
25-34	5 (33.3)	
35-44	2 (13.33)	
45-54	3 (20)	
55-64	3 (20)	
Total	15 (100)	**38.6± 14.27**

Mean age of the patients was 38.6±14.27 years. Maximum post-traumatic kyphotic patients belonged to (25-34) years and post-tubercular kyphotic patients belonged to (55-64) years of aged group.

Gender of the study population:

All the 15 study population were enrolled irrespective of gender. After completing the study, we found majority of study population were male.Distribution of study population according to gender (Table II).

Table II: Gender distribution among the study population

Gender	Frequency, n (%)
Male	10 (66.67)
Female	5 (33.33)
Total	**15 (100)**

Study population was male predominant (66.67%). Male and female ratio was 2:1.

Occupation of study population:

Study sample was taken irrespective of occupation. The study populations were farmer (5), day labourer (4), housewife (3), service holder (1), businessman (1) and student (1). Distribution of study population according to occupation (Table III).

Table III: Occupation among the study population (n=15)

Occupation	Frequency, n (%)
Farmer	5 (33.33)
Day labourer	4 (26.67)
Housewife	3 (20)
Service Holder	1 (6.67)
Businessman	1 (6.67)
Student	1 (6.7)
Total	**15 (100)**

Maximum patients were farmer (33.33%) and Day labourer (26.67%) then Housewife (20%), Service Holder (6.67%), Businessman (6.67%) and Student (6.67%).

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Clinical manifestations of the study population:

Clinical manifestations was one of the variables into this study. Distribution of study population according to clinical manifestations (Table IV).

Table IV: Clinical manifestations of the study population (n=15)

Clinical manifestations*	Frequency, n (%)
Back pain with lower limb weakness	15 (100)
Kyphosis	15 (100)
Gait abnormality	8 (53.33)
Motor weakness of lowe limbs	8 (53.33)
Sensory disturbance of lower limbs	4 (26.67)
Bowel and bladder involvement	1 (6.67)

*Multiple responses

Fifteen patients (100%) had back pain with lower limb weakness and kyphosis. Eight patients (53.33%) had gait disturbance with motor weakness of lower extremities. Four patients (26.67%) had sensory disturbance. One patient (6.67%) presented with bowel-bladder involvement.

PSO level:

Total number of study population was 15. All the study population had kyphosis at dorso-lumbar region and PSO was done at single level. Distribution of population according to PSO level (Table V).

Table V: PSO level among study population (n=15)

Vertebral body for PSO	Frequency, n (%)
D_{12}	4 (26.67)
L_1	10 (66.67)
L_2	1 (6.67)
Total	15 (100)

Most commonly PSO were done at L_1 (66.67%), followed by D12 (26.67%) and L_2 (6.67%).

Peri-operative complications:

Peri-operative complication was one of the surgical variables in our study. In this study dural tear, wound infection and implant failure were the peri-operative complications. Distribution of study population according to per and post-operative complications (Table VI).

Table VI: Peri-operative complications (n=15)

Complications	Frequency (n)	Percentage (%)
Per-operative		
Root injury	0	0
Dural tear	1	6.67
Post-operative		
CSF leakage	0	0
Wound infection	1	6.67
Implant failure	1	6.67

A total of three major complications (20%) were observed. One (6.67%) patient had per-operative complication (Dural tear) (Case 5). Post-operative complications were noticed in 2 patients: One (6.67%) patient suffered from early post-operative complication (Superficial wound infection) (case13) and one (6.67%) patient presented with late post-operative complication (Implant failure) (case 3).

Duration of total hospital stay:

Total hospital stay was one of the surgical variables in this study. All the patients were stayed in hospital ranged from 14-23 days. Distribution of study population according to duration of total hospital stay (Table VII).

Table VII: Duration total hospital stay (n=15)

Total hospital stay (in days)	**Frequency, n (%)**	**Mean**±SD
10-14	6 (40)	
15-19	6 (40)	
20-24	3 (20)	
Total	15 (100)	**16.67±2.94**

Mean hospital stay was 16.67±2.94 days, ranged from 14-23 days.

Mean VAS score at different time points:

All the 15-study population were assessed by VAS score pre-operatively and post-operatively at 1, 3, 6 and 12 months of follow up to see the level of improvement of pain status. Distribution of study population according to VAS score at different time points (Table: VIII).

Table VIII: Mean VAS score in all patients at different time points (n=15)

Time point	Mean± SD	Range (Min-Max)	p value
Pre-operative	7.2±0.41	7-8	
After 1 month	5.2±0.43	5-6	
After 3 months	3.6±0.48	3-4	
After 6 months	2.66±0.49	2-3	
After 12 months	**2.4±0.59**	2-4	**<0.001**

*Paired t- test was performed comparing pre-operative Vs final follow-up at 12 months.

Pre-operatively, mean VAS score of all patients was 7.2±0.41 (7-8) whereas post-operatively VAS score was decreased significantly (after 1, 3, 6 and 12 months of follow up 5.2±0.43, 3.6±0.48, 2.66±0.49 and 2.4±0.59 respectively) (p value <0.001).

Assessment according to Bridwell fusion criteria:

Radiological outcome was assessed post-operatively by Bridwell grading system (Appendix VIII). Radiological fusion with remodeling and trabeculae was found in majority of patients after 6 and 12 months of follow up. No patient had experienced non-union (grade IV) during all of the post-operative follow up. Distribution of study population according to Bridwell fusion criteria (Table: IX).

Table IX: Assessment according to Bridwell fusion criteria (n=15)

Bridwell grade	After 3 months n (%)	After 6 months n (%)	After 12 months n (%)
Grade I	0 (0)	11 (73.33)	14 (93.33)
Grade II	11 (73.33)	4 (26.67)	1 (6.67)
Grade III	4 (26.67)	0 (0)	0 (0)
Grade IV	0 (0)	0 (0)	0 (0)

Statistical analysis showed, Grade I fusion criteria was significantly increased at 12 months follow up (93.33%) compared to 3 months follow up (0%).

Clinical outcome according to Oswestry Disability Index (ODI) score:

Pre-operative and post-operative (after 12 months of surgery) comparison of clinical outcome according to Oswestry Disability Index (ODI) score (Appendix IX) during follow up. Distribution of study population according to ODI score (Table: X).

Table X: Assessment according to Oswestry Disability Index (ODI) score (n=15)

Time point	Mean±SD	Range (Min-Max)	p value
Pre-operative	55.27±5.06	48-65	
After 1 month	45.8±4.55	40-55	
After 3 months	34.6±4.73	30-45	
After 6 months	23.8±4.05	20-36	
After 12 months	14±6.70	8-35	**<0.001**

*Paired t- test was performed comparing pre-operative Vs final follow-up at 12 months.

Pre-operatively, mean ODI score of all patients was 55.27 (48-65) whereas post-operatively VAS score was decreased significantly after 1, 3, 6 and 12 months of follow up (45.8, 34.6, 23.8 and 14 respectively) compared to pre-operative status (p value <0.001).

Assessment of kyphotic angle:

Pre-operative and post-operative comparison of kyphotic angle, mean correction of Kyphosis with loss of kyphosis are significant variables of our clinical study. Distribution of study population according to Kyphotic angle (Table: XI).

Table XI: Assessment of kyphotic angle (n=15)

Time point	Kyphotic Angle (°) (Mean± SD)	p value
Pre-operative	42.51±3.10	
Post-operative	5.34±0.85	<0.001
Correction	37.39±0.83	
Loss of correction	1.56±0.26	

*Paired t- test was performed comparing pre-operative Vs final follow-up at 12 months.

Pre-operativel kyphotic angle was 43.23±2.49° and post-operative kyphotic angle was 5.34±0.85°. Mean correction of kyphosis was 37.39±0.83° with loss of correction 1.56±0.26° (p value < 0.001).

Assessment according to Dennis work scale:

Overall improvement was assessed by Dennis work scale (Appendix X). Distribution of study population according to Denis work scale (Table: XII).

Table XII: Assessment according to Dennis work scale (n=15)

Time point	Mean	Range (Min-Max)	p value
Pre-operative	4.47±0.49	3-5	
After 3 months	2.53±0.49	2-3	
After 6 months	1.6±0.49	1-2	
After 12 months	1.27±0.44	1-2	**<0.001**

*Paired t- test was performed comparing pre-operative Vs final follow-up at 12 months.

Pre-operative Denis work score was 4.47±0.49 and post-operatively 2.53±0.49, 1.6±0.49 as well as 1.27±0.44, respectively (p value <0.001).

Assessment according to Modified Macnab's criteria:

Overall improvement was assessed by Modified Macnab's criteria (Appendix XI). Excellent improvement were noticed in majority patients after 3, 6 and 12 months of post-operative follow up. No patient had experienced poor outcome during all of the post-operative follow up. Distribution of study population according to Modified Macnab's criteria (Table: XIII).

Table XIII: Assessment according to Modified Macnab's criteria (n=15)

Status	After 1 month n (%)	After 3 months n (%)	After 6 months n (%)	After 12 months n (%)
Excellent	0 (0)	0 (0)	10 (66.67)	12 (80)
Good	12 (80)	14 (93.33)	5 (33.33)	3 (20)
Fair	3 (20)	1 (6.67)	0 (0)	0 (0)
Poor	0 (0)	0 (0)	0 (0)	0 (0)

Excellent outcome was significantly increased after 12 months of follow up (80%) compared to 1 month follow up (0%).

DISCUSSION

In this study, mean age was 38.6±14.27 years. Maximum post-traumatic kyphotic patients belonged to (25-34) years and post-tubercular kyphotic patients belonged to (55-64) years of aged group. Ahmed Sleem (2017) found almost similar mean age (38.43±6.63 years) when he studied on 14 post-traumatic kyphotic patients with age ranging from 26-48 years. Mean age was 37.6 yrs for post-tubercular kyphotic patients in the study of Kim et al. (2012).

In present study, male and female ratio was 2:1. Kalra et al. (2006) also found male and female ratio 2:1 on 15 rigid post-tubercular kyphotic patients. Ahmed Sleem (2017) found male and female ratio 2.5 : 1.

Maximum patients were farmer (33.33%) and Day labourer (26.67%) then Housewife (20%), Service holder (6.67%), Businessman (6.67%) and Student (6.67%). Hard working people are mostly vulnerable for spine trauma and lower socio-economic class people are prone to tubercular infection.

In our study, fifteen (100%) patients had back pain with lower limb weakness and kyphosis. Eight patients (53.33%) had gait disturbance with motor weakness of lower extremities. Four patients (26.67%) had sensory disturbance. One patient (6.67%) presented with bowel-bladder involvement. Gokce et al. (2008) found angular kyphosis, back pain, functional and neurologic deformity in their study.

We did PSO mostly at L_1 (66.67%), followed by D_{12} (26.67%) and L_2 (6.67%). Barcelos et al. (2019) did PSO of L_1 in the thoracolumbar junction post-tubercular kyphotic patients. PSO was

done below L_1 on 25 patients by Barrey et al. (2014) and various level by Mummaneni et al. (2008).

We observed three major complications (20%). One (6.67%) patient had per-operative complication (Dural tear) (Case 5). Post-operative complications were noticed in 2 patients: One (6.67%) patient suffered from early post-operative complication (Superficial wound infection) (case13) and one (6.67%) patient presented with late post-operative complication (Implant failure) (case 3). Rods were broken at 10^{th} months of PSO at the index level vertebra and underwent revision surgery without any morbidity. Bridwell et al. (2003) found rod breakage at the index level vertebra or in adjacent vertebrae. Pedicle screws were broken between 6-12 months following surgery of Ashok et al. (2010). Barrey et al. (2014) found major complications in 20% of their study population. Ahmed Sleem (2017) found dural tears and postoperative wound infections.

In this study, average hospital stay was 16.67 days which was ranged from 14-23 days. Most of our patients were discharged on 7^{th} post-operative day. But duration of total hospital stay is increased due to pre-operative longer duration of hospital stay. Mummaneni et al. (2008) found mean hospital stay 14 days.

In present study, Pre-operatively mean VAS score of all patients was 7.2±0.41 (7-8) whereas post-operatively VAS score was decreased significantly after 1, 3, 6 and 12 months of follow up (5.2±0.43, 3.6±0.48, 2.66±0.49 and 2.4±0.59, respectively) compared to pre-operative status (p value <0.001). Barrey et al. (2014) Showed, VAS decreased from 7.5±2 to 3.2±2.5 at last follow up. VAS was also decreased from 7.8±1.6 to 3.2±1.8 (Hu et al. 2016) and 8.21±0.77 to 2.5±0.75 (Ahmed Sleem, 2017).

According to Bridwell fusion grading system, radiological fusion with remodeling and trabeculae (grade I) in majority patients after 6 and 12 months of follow up (73.33% and 93.33% respectively). Bridwell Grade I fusion was significantly increased after 12 months of follow up compared to 3 months (p value <0.001). Kim et al. (2012) and Xi et al. (2013) observed solid union without pseudarthrosis. Hu et al. (2020) and Ashok et al. (2010) also reported significant bony union in their study.

Pre-operatively, mean ODI score of all patients was 55.27 (48-65) and 14.0 at final follow up. Kalra et al. (2006) found improvement of mean ODI from 56.26 pre-operatively to 11.2 and Gokce et al. (2008) found 54.2 preoperatively to 15.2 at final follow-up.

Pre-operative kyphotic angle was 43.23±2.49° and post-operatively 5.53±0.71°. Mean correction of kyphosis was 37.39±0.83° and loss of correction was 1.56±0.26°; which indicates significant correction of kyphotic angle (p value <0.001). The regional kyphotic angle significantly improved from 42.07±5.28° to 2.67±2.58° after PSO on 14 post-traumatic kyphotic patients (Ahmed Sleem, 2017). Final correction of kyphotic angle were obsered 40.2° by Xi et al. (2013), 38.4° by Ahmed Sleem (2017) and 36.2° by Kim et al. (2012); which are similar (37.39°**)** to this study. Xi et al. (2013) observed loss of correction 1.7° at the latest follow-up, it signifies near similar (1.56°**)** to our study.

Pre-operative Denis work score was 4.47±0.49 and post-operative score was 1.27±0.44 at latest follow up with p value <0.001. Ahmed Sleem (2017) found improvement of Denis work scale from 4.43±0.49 to 1.64±1.23 at latest follow up.

Post-operative follow up at 12 months after surgery demonstrated, 80% patients had excellent outcome and 20% had good outcome. No poor and fair outcome were noticed. Excellent outcome

was significantly increased at 12 months compared to 1 month follow up (p value <0.001). Near similar result (90.7%) were found by Kim et al. (2012) and Barcelos et al. (2019) at their last follow up.

CONCLUSION

PSO is highly effective to restore dorso-lumbar lordosis and correct sagittal imbalance. A greater degree of kyphosis correction (>30° but <40°) can be obtained with a single pedicle subtraction osteotomy. For post-traumatic and post-tubercular kyphotic deformity, this procedure is an effective with minimal peri-operative complications which provides considerable and sustained improvement in pain control with quality of life.

LIMITATIONS

There were some limitations in the study:

- The study population might not represent the whole community.
- As the sample was taken purposively, there may be chance of bias.
- The study and follow-up period were short.
- We have no neuromonitor.

RECOMMENDATION

- Large sample size with longer follow-up.
- Multicentric study can be done.
- Instrumental support like neuromonitor need for better outcome.

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