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The Evaluation of Effectiveness of Pedicle Subtraction Osteotomy on Thoracic Level in Spinal Deformity Patients

Omurga Deformiteli Hastalarda Torakal Seviyede Uygulanan Pedikül Çıkarma Osteotomisi Sonuçlarımız

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ABSTRACT

Objectives: Classical instrumentation may be insufficient in the surgical treatment of rigid spinal deformities with structural changes in bone tissue. Many different types of osteotomy have been described to correct such rigid deformities. In this study, we aimed to evaluate the clinical and radiological results of pedicle subtraction osteotomy (PSO) applied at the thoracic level in patients with coronal and/or sagittal plane spinal deformity.

Methods: 61 of the 123 cases, who underwent PSO for spinal deformity between 2010 and 2013, were included in the study. Pre- and post-operative ortho-radiography was performed; angles (scoliosis, kyphosis, and lordosis angles) and global sagittal balance were measured. Duration of operation, bleeding and complications were noted. SF-36 scoring was used for clinical outcome.

Results: This study was consist of 30 male and 31 female patients including 28 scoliosis, 23 kyphosis and 10 ankylosing spondylitis cases. Post-operative mean Cobb angle was 62%, sagittal balance was 42%, kyphosis angle was 38%, thoracic kyphosis angle was 61%, and lordosis angle was 19.44% corrected ($p<0.001$). When radiological data were evaluated, significant improvement was observed in the angles of kyphosis and lordosis after PSO surgery. The eight parameters of SF-36 showed an increase in all patients, while the least change was observed in the pain parameter.

Conclusion: PSO surgical technique is effective in patients with spinal deformity with sagittal balance disturbance at the lumbar region as well as thoracic level.

Keywords: Deformity; pedicle subtraction osteotomy; spine; thoracal; vertebrae osteotomy.

ÖZET

Amaç: Kemik dokusunda yapısal değişiklikler olan rijit omurga deformitelerinin cerrahi tedavisinde klasik enstrümantasyon yetersiz olabilir. Bu tür rijit deformiteleri düzeltmek için birçok farklı osteotomi türü tanımlanmıştır. Bu çalışmada, koronal ve/veya sagital düzlem spinal deformitesi olan hastalarda torasik düzeyde uygulanan pedikül çıkarma osteotomisinin (PSO) klinik ve radyolojik sonuçlarının değerlendirilmesi amaçlandı.

Yöntem: 2010-2013 yılları arasında spinal deformite nedeniyle PSO uygulanan 123 olgunun 61'i çalışmaya dahil edildi. Ameliyat öncesi ve sonrası ortoradyografi yapıldı; açılar (skolyoz, kifoz, lordoz açıları) ve global sagital denge ölçüldü. Operasyon süresi, kanama ve komplikasyonlar kaydedildi. Klinik sonuç için SF-36 skorlaması kullanıldı.

Bulgular: Bu çalışma, 28'i skolyoz, 23'ü kifoz ve 10'u ankilozan spondilit olgusu olmak üzere 30 erkek ve 31 kadın hastadan oluşuyordu. Postoperatif ortalama Cobb açısı %62, sagital denge %42, kifoz açısı %38, torasik kifoz açısı %61 ve lordoz açısı %19,44 olarak düzeltildi ($p<0,001$). Radyolojik veriler değerlendirildiğinde PSO cerrahisi sonrası

kifoz ve lordoz açılarında anlamlı düzelme gözlendi. SF-36'nın sekiz parametresi tüm hastalarda artış gösterirken, ağrı parametresinde en az değişiklik gözlendi.

Sonuç: PSO cerrahi tekniği, lomber bölgede ve torasik düzeyde sagital denge bozukluğu olan spinal deformitesi olan hastalarda etkilidir.

Anahtar sözcükler: Pedikül çıkarma osteotomisi; omurga; deformite; vertebra osteotomisi; torakal.

The emergence and development of new fixation techniques and instrumentation in spine surgery have led to improvements in deformity reconstruction. Correction and fusion with instrumentation alone are not sufficient to correct advanced sagittal and/or coronal plane imbalances of the deformity.[1] Classical instrumentation methods in the surgical treatment of spondyloarthropathies such as rigid adult scoliosis, severe sagittal plane imbalances, ankylosing spondylitis, and psoriatic arthritis can be insufficient to correct structural changes in bone tissue.

Osteotomy types such as peduncle subtraction osteotomy (PSO), partial pedicle subtraction osteotomy, Smith-Petersen osteotomy, and Chevron osteotomy have been described to correct deformities.[2-4] Among the osteotomy options available, PSO, which decreases patient morbidity with the application of anterior release, posterior shortening, and posterior fixation through a single approach, is also an increasingly popular surgical technique for providing high-grade angular correction.[5] This osteotomy (PSO) is often used for the lumbar region and reports of clinical outcomes related to its use for the thoracal region are very few and insufficient.[6-7] In many clinical reports, it has been shown that this osteotomy technique can provide approximately 30–40 degrees of correction in the lumbar region. However, there are very few data on the corrective capacities of PSO in the thoracal region.[6]

The aim of the present study was to evaluate the clinical and radiological outcomes of patients who underwent thoracal PSO and thus evaluate the capacity and adequacy of this technique in terms of correction of deformity, complications, and outcomes.

Methods

This study was carried out in the Department of Orthopedics and Traumatology after having been approved by the Ethics Committee of Sakarya University (number 71522473.050.01.04/31).

Between January 2010 and April 2013, 123 patients underwent PSO surgery in our clinic. 61 patients who had inclusion criteria were included in the study.

PSO surgery was performed in patients who had undergone previous surgery or had not been operated on for sagittal plane deformity (sagittal vertical axes ≥60 mm) that did not decrease below 50 degrees in the bending radiographs and that recovered less than 30%.

Patients, a sagittal vertical axis >60 mm, a rigid sagittal plane deformity or a rigid coronal plane deformity that does not decrease below 50 degrees in the bending radiographs and/or improves less than 30%, administered during PSO surgery between T1 and T12 levels were included in our study.

Without pre-operative and/or post-operative anteroposterior and lateral orthoradiography, isolated PSO applied to the lumbar region, treated with osteotomy techniques other than PSO, a follow-up period of >2 years were excluded from our study.

The pre-operative clinical evaluation was performed using patients' sociodemographic data, medical history, clinical and neurological examinations, and a questionnaire for quality-of-life scoring, Short Form-36 (SF-36), by an orthopedic surgeon experienced in spinal surgery on an intraobserver basis. In the evaluation of the graphs, two radiologists clinically experienced in spinal radiology and one orthopedic surgeon experienced in spinal surgery preoperatively evaluated the angles of curvature (Cobb's method), global thoracic kyphosis angle (T2-T12), and lumbar lordosis angle (L1-S1) in the coronal and sagittal planes. Sagittal balance was measured and calculated by reference to the distance of the line from C7 to the posterior corner of S1.

All patients were operated on in prone position. Somatosensory and transcranial motor evoked potentials were monitored intraoperatively in all patients. First, transverse processes were dissected and excised at the level of the PSO. Then the costotransverse joint was separated by entering a costotransverse joint space with a thin Cobb elevator. Before

the laminectomy, prednisolone was administered to all patients according to the NASCIS II protocol.[7-9] Posterior elements were resected, and total laminectomy was performed. Afterwards, the pedicle retractors were placed on the medial spinal cord and both pedicles were excised with the help of a circumferential gouge osteotome. To maintain continuity of the anterior cortex, straight and 80 curved osteotomes were used and V-shaped closed wedge osteotomy was performed. Bone structures that were removed during resection were used for posterior fusion as an autograft source after the posterior instrumentation. Posterior spinal instrumentation and fusion were performed.

Postoperatively, control radiographs were taken on the 1st day, at 3 and 6 months, and after at least 2 years. Coronal and sagittal curvature angles, global thoracic kyphosis angle, lumbar lordosis angle, and sagittal balance were measured on all radiographs. Duration of operation, amount of bleeding, and major (mortality, infection, and neurological deficiency) and minor (superficial infection and implant failure) perioperative complications were recorded. The SF-36 test performed postoperatively was used in the clinical evaluation. To prevent thromboembolic complications 40 mg/0.4 mL enoxaparin (Clexane®; Sanofi-Aventis, Istanbul) was given for 30 days after surgery to all patients.

Statistical Analysis

Statistical analyses were performed with SPSS 22.0 for Mac (SPSS Inc., Chicago, IL, USA). $p<0.001$ was considered statistically significant. The paired Student's t-test was used for comparisons between Cobb, kyphosis, and lordosis angles before and after surgery.

Results

The average age of the men was 31.71±5.2 (7–69) years and of the women was 31.65±9.2 106 (8–76) years. 30 (49.18%) of participants were male and 31 (50.82%) were female.

The mean follow-up period was 63.4±5.5 (46–72) months. The mean amount of bleeding was 1255.94±105 ml (550–1800). The mean operative time was 249.63±25.7 min (155–420). Of these patients, 51 underwent single level thoracic osteotomy, while six patients underwent 2 levels (thoracal+lumbar) and four patients underwent 3 levels (thoracic+thoracic+lumbar) of osteotomy. All ten patients who underwent multiple PSOs had ankylosing spondylitis. Other demographic characteristics of the patients are given in detail in the table (Table 1).

Table 1. Clinical Presentation Characteristics

	Idiopathic Scoliosis (n:2)
Distribution of the Patients	Neuromuscular Scoliosis (n:3)
	Congenital Kypho-Scoliosis (n:16)
	Revision Kypho-Scoliosis (n:7)
	Scheuermann's Kyphosis (n:4)
	Congenital Kyphosis (n:10)
	Post-junctional Kyphosis (n:4)
	Post-traumatic Fracture Kyphosis (n:5)
	Ankylosan Spondylitis (n:10)
Osteotomy	PSO (n:51)
	PSO+VCR (n:2)
	PSO+Ponte (n:2)
PSO Level	T1-T4 (n=4; 6.15%)
	T5-T8 (n=15; 23.08%)
	T9-T12 (n=46; 70.77%)

In addition to PSO, vertebral column resection (VCR) was performed in two patients and Ponte osteotomy was performed in seven patients. Six of the patients undergoing additional osteotomy had congenital kypho-scoliosis and three patients had neuromuscular scoliosis.

In two cases (one congenital scoliosis and one congenital kyphosis) (3.28%), loss of nerve conduction was observed by neuromonitoring during intraoperative reduction and fixation. Iatrogenic pleural tear occurred in one congenital kyphoscoliosis case (1.64%). Early wound infection was observed in three cases (4.91%). Two of these cultures were found to be methicillin-sensitive Staphylococcus aureus and Streptococcus epidermidis in one patient (1.64%). One patient (1.64%) developed late wound infection 1 year after the surgery. One patient (1.64%) had hypertension that did not respond to intraoperative medical treatment despite surgical bleeding control.

Cobb's angle, thoracic kyphosis, local kyphosis, and lumbar lordosis angles and sagittal balance were evaluated preoperatively and postoperatively. There was a significant improvement in all patients ($p<0.001$) (Table 2).

The instrumentation level was a minimum of 5 (T10-L2) and a maximum of 18 (T1-S1) levels of the spine (Fig. 1). The most frequent instrumentation interval was between T3 and L2. In addition, the highest level of instrumentation was at C6, while the lowest level was at S1 and the iliac crest of the pelvis.

Table 2. Radiological Results

	Preoperative	Preoperative	Correction (mm)	Significance (Pre vs. Post)
Cobb's Angle (Scoliosis)	78.53°±12.44 (42°-145°)	29.96°±9.35 (5°-72°)	42.15± 13.53 (110-0)	<0.001
Thoracic Kyphosis (T1-T12)	72.51°±5.68 (112°-44°)	45.26°±6.89 (84°-20°)	27,25°±9.19 (37.58%)	<0.001
Local Kyphosis (PSO Level)	50.12°±14.67 (110°-20°)	19.10°±12.53 (65°-4°)	27,25°±9.1 (37.58%)	<0.001
Lumbar Lordosis (L1-S1)	62.17°±2.41 (101°-0°)	50.07°±7.67 (83°-12°)	27,25°±9.19 (37.58%)	<0.001
Sagittal Balance	83.09±21.75 mm (210-10)	42.15±13.53 mm (110-0)	27,25°±9.19 (37.58%)	<0.001

The thoracic kyphosis resulted from the angle formed by the lines drawn across the upper and the lower endplates of T1 and T12, respectively. The local kyphosis was defined by the angle across the upper and lower endplates of the vertebra chosen to perform the osteotomy.

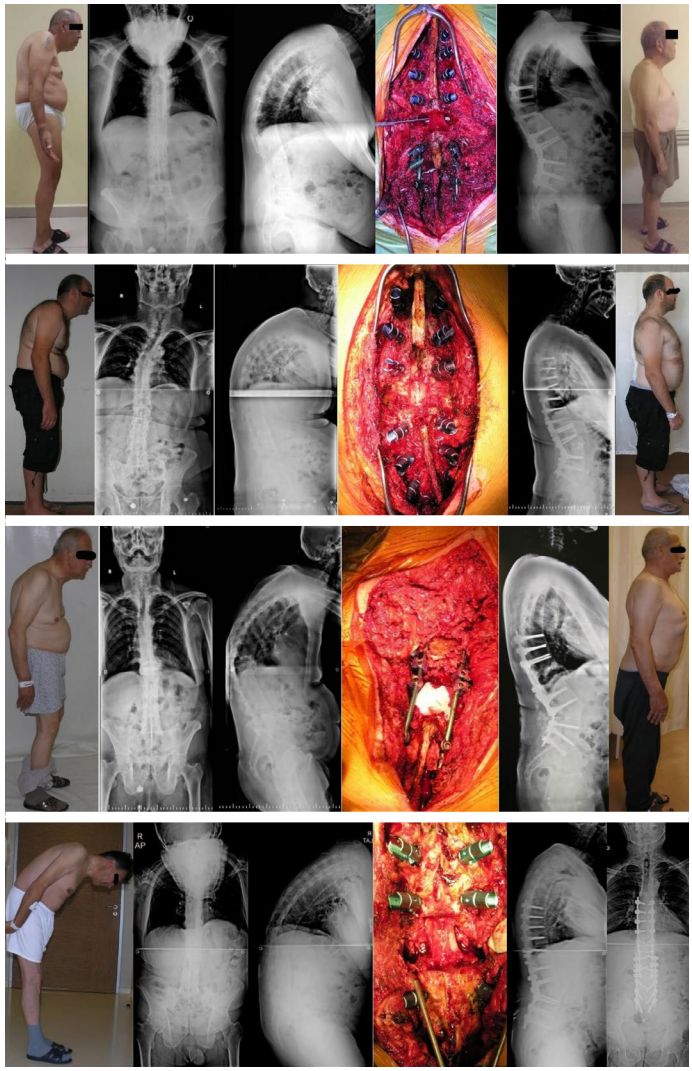

Figure 1. Preoperative, intraoperative and postoperative imagines of some cases.

When the SF36 levels in the pre-operative and post-operative periods were evaluated, the scores were significantly increased in all eight subcategories, and this was statistically significant (p<0.05) (Table 3).

Tables 3. Comparison of SF-36 Preoperatively and Postoperatively

SF-36	PREOP (n=61) X±SD	POSTOP (n=61) X±SD	p
General Health	42.4±12.64	62.3±13.05	<0.001
Physical Function	42.3±19.1	74.09±16.39	<0.001
Role Physical	30.4±18.93	64±16.71	<0.001
Bodily Pain	41.3±8.13	52.9±11.88	<0.001
Role Emotion	41.5±18.19	71.6±17.65	<0.001
Energy / Vitality	41.6±13.78	68.4±15.78	<0.001
Mental Healty	41.1±8.22	68.4±15.78	<0.001
Social Function	46.8±17.59	77.8±14.28	<0.001

Discussion

In our study, we found that thoracic PSO is an effective surgical method clinically and radiologically in patients with spinal deformity.

Rigid thoracic deformities are serious spinal problems to deal with. Previously, these patients were treated with classic anterior release and posterior resection and fusion with instrumentation. Thanks to PSO, the 3 columns of the spine can be accessed at any time and this gives a chance to rule out the morbidity problems that occur in the anterior procedure.[10]

Lehmer et al.[11] reported the results of four thoracic PSO cases (T10, n=1; T11, n=1; T12, n=2). The PSO technique was performed at the distal thoracic levels. Accordingly, in the four cases the mean correction rate was 29.5°. The lumbar PSO studies conducted by Kim et al.,[12] they included 2 distal thoracic PSO cases (T10, n=1; T12, n=1) as subgroups. In spite of the positive results obtained, they emphasized that bone fragments should be well cleaned to prevent cord compression, especially if T12 level PSO is essential.

PSO is frequently applied to the lumbar spine in patients with flatback deformity. At the thoracic level, it is often used but is limited to the distal thoracic region. In several aspects, the thoracic PSO differs from the lumbar PSO. For the thoracic PSO to be fully closed first, it is necessary to free the costae that have been articulated with discs above and below the osteotomy and to exclude the ribs if necessary. Second, 161 the lumbar PSO is mostly applied at the level of distal conus medullaris or cauda equina, whereas the thoracic PSO is applied at the level of the spinal cord. Therefore, during the closing of the osteotomy, a dural kink may be formed, disrupting the spinal cord blood supply and leading to cord and neurological dysfunction.[6] Lewis et al.[13] reported that more upper thoracic correction could be achieved with wide costa resection. In addition, if the osteotomy level is above T10, the pads should be placed transversally. The osteotomy site should be compressed using the proximal part of the instrumentation rather than surgical table movement.

Correction rate varies according to the region of the PSO. Due to the thoracic vertebrae corpus tending to be wedge-shaped rather than squared, although the closure area in the posterior region is less than that of the typical lumbar PSO, it is more efficient to perform PSOs than many Smith-Petersen osteotomies.[6]

As the distal to proximal part of the thoracic region, the dimensions of the vertebral corpus are changed and shortened, and the shape of the corpus transforms toward the wedge. O'Shaughnessy et al.[6] showed that the PSO technique performance ratios applied to the middle and lower thoracic region with the upper thoracic region corresponding to the PSO decreased proximally due to anatomy. Hayashi et al.[14] showed that maximum correction angle at the lumbar spine was 45.7° and 37.3° at the T4 level with the correct PSO applications. In the literature, the angle of lumbar spine correction is 31° and the angle of thoracic spine correction is 24° with PSO.[15] In our study, we found that the degree of correction with PSO decreased from distal levels of the vertebra to proximal levels. In their series of 28 cases of thoracic kyphosis, Faundez et al.[16] reported the upper thoracic correction angle was 17.5°, the lower thoracic correction angle was 26.2°, and the global thoracic correction angle was 24.2°. Bakaloudis et al.[17] reported 37.3% correction in 12 pediatric cases with a single-level thoracic PSO and reported a 23.5° angle of kyphosis correction. In a study by O'Shaughnessy et al.[6] in 15 cases in 2009, 20–25 mm closure of the thoracic level resulted in safe osteotomies without neurological deficits; moreover, the mean kyphosis angle decreased from 75.7° to 54.3°, and the global sagittal balance decreased from 106.1 mm to 38.8 mm. Cacho-Rodrigues et al.[18] reported that the kyphosis correction angle at the lower thoracic levels was 10° and at the upper thoracic level was 41° in 17 cases followed up for 55 months. They achieved a decrease in local kyphosis angle from 55° to 15° and in thoracic kyphosis angle from 75° to 50°. In our study, the mean kyphosis angle decreased from 72.51° to 45.26° and the mean correction 189 was 37.58%. In addition, the mean sagittal balance decreased from 83.09 to 42.15 mm, resulting in a 49.27% correction.

The thoracic deformity correction rates in our cases were consistent with those reported in the literature. In cases of ankylosing spondylitis, total spinal fusion occurs, which disrupts the sagittal balance. To achieve sagittal balance in these patients, two or more PSOs are required.[12] In 2001, Chen et al.[19] reported good/excellent results of 98.7% for two-level PSO applied in 14 cases in a 78-case series study, the majority of which were lumbar PSO. In the series of nine patients with ankylosing spondylitis reported by Zhang et al.,[20] PSO was applied to all patients between T12 and L3 levels and the global kyphosis correction rate was reported as 54°. In our study, we applied PSO to different thoracic regions according to the indications of the cases. In the selection of the spine to which PSO was to be applied, we made anatomical preparations in accordance with the region. We applied the osteotomy to the apical region or the center of the junctional deformity in patients with kyphosis. Apart from the patients with ankylosing spondylitis, we found that one-level PSO was sufficient for correction of the deformity. We applied two- or three-level PSOs to all of our patients with ankylosing spondylitis.

PSO is a major surgical procedure. Therefore, early or late complications may occur at low rates. Mao et al.[21] reported the following complications in 71 patients with ankylosing spondylitis who underwent thoracolumbar kyphosis correction with the PSO technique: Five cases of dural tears, 5 cases of screws misplaced, 2 cases of transient brachial plexus injuries, 2 cases of rod fractures, and 2 cases of traumatic cervical fractures. Faundez et al.[16] reported somatosensory reduction, 2 dural tears, 1 deep infection, and 1 pleural tear in 1 case. Lehmer et al.[11] reported a 19.5% rate of neurological deficits. In our study, we obtained much better results compared to the literature in terms of operation time and intraoperative bleeding.

According to the clinical results of the cases evaluated with SF-36, at the end of a very troublesome and exhausting process for the patient and the surgeon, all patients were quite satisfied with this major surgery. We can say that excellent results are obtained especially in terms of mental health and physical and social function. As it is almost impossible to achieve a complete mechanical balance, as in all deformities treated with fusion, partial improvement in spinal pain has been observed.

However, there are some limitations in our study. First of all, our study is a retrospective study. Another limitation is that the patients who underwent PSO were not a homogeneous group. However, the small number of patients with thoracic PSO indications caused the groups not to be homogenized.

Conclusion

PSO surgical technique is effective in patients with spinal deformity with sagittal balance disturbance at the lumbar region as well as thoracic level.

Disclosures

Ethics Committee Approval: This study was carried out in the Department of Orthopedics and Traumatology after having been approved by the Ethics Committee of Sakarya University (number 71522473.050.01.04/31).

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

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