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USING THE PEDICLE SUBTRACTION OSTEOTOMY FOR THE CORECTION OF SAGITTAL IMBALANCE IN SPINE

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The aim of this study was was to compare the results of different surgical techniques used in the correction of spinal sagittal imbalance, in patients with rigid curves. Twenty-three patients operated in our hospital, using different surgical techniques: pedicle subtraction osteotomy, Smith-Petersen osteotomy or vertebral column resection were included. The patients were evaluated preoperative using our spine radiology protocol and also an MRI examination was performed. The surgical planning included determining the levels of fixation, level of the osteotomy, and the value of correction. The type of osteotomy was chosen based on the value of correction needed, determined using freeware available software. The patients were evaluated pre- and post-operatory using the Oswestry Disability Index and radiologically with the standard protocol. We managed to restore the normal sagittal balance in the spine using a single level pedicle subtraction osteotomy, allowing us a correction of 30-40 degrees. The pedicle subtraction osteotomy is an effective procedure, allowing good correction of the deformity through single level single side approaches, having a positive impact on the quality of patient's life.

Keywords: spine sagittal imbalance; osteotomy; pedicle subtraction

INTRODUCTION

In a normal balanced human spine, in the standing position the C7 plumb line will fall through the posterosuperior corner of the first sacral vertebra. The sagittal imbalance of the spine is a situation in which the C7 plumb line falls more than 5cm away (anterior or posterior) from the normal position. A sagittal deformity as main element causing the imbalance can appear in a large number of situations from ankylosing spondylitis, degenerative disease, post-traumatic, congenital, flatback syndrome, iatrogenic conditions and Scheuermann disease. A fixed sagittal imbalance has a major influence on the life as the patients live with a continuous sense of imbalance, leaning forward, fatigue and pain with little response to medication or other therapies, another major complaint is the inability to see the road ahead[1]. The patients with sagittal plane imbalance, like most deformities of the spine, can be placed in one of the two major groups: flexible curves – patients that can be treated by instrumenting the curves and simple intraoperative correction maneuvers and the patients with rigid curves, rigid deformity which need an osteotomy for correction[1-5]. We use the osteotomy to restore the sagittal balance, improving this way the quality of patient's life and the ability to move.

MATERIAL AND METHODS

This is a retrospective study on a small group of patients (n=23) operated in the *"Foisor"* Hospital, with a follow-up period of 1 to 12 years. The study group was made of 10 patients (6 women, 4 men; mean age 48 years old) which were operated using the single level pedicle subtraction osteotomy technique and the witness group composed of 11 patients (6 women, 5 men, mean age 44 years old) operated using the Smith –Petersen osteotomy. There were also two patients operated with the vertebral column resection and reconstruction technique for major focal deformity.

Preoperative evaluation of the patients was composed of standard blood tests, respiratory probes, neurologic examination, and MRI examination of the lumbar spine – focused on the level of the planned osteotomy. The standard radiology protocol in our hospital consists of standing PA(postero-anterior) and LL(latero-lateral) x-rays that include the whole spine: from C1 level to the proximal 10cm of the femurs[2] Figures 5,6. We use the LL x-rays to determine the spinopelvic parameters (pelvic incidence, pelvic tilt and sacral slope) and the real values of the thoracic kyphosis (determined as the Cobb angle T1-T12) and the lumbar lordosis (the Cobb angle from superior plate of L1 to the superior plate of S1) and use mathematic equations to determine the predicted values of spine curves (LL = P.I.+ 9°). The position of the coxofemural joints is determined as the

hip flexum associated with knee flexum (determined by clinic examination) are signs of compensatory mechanisms for sagittal imbalance. After the measurements and the initial calculations, all the patients were devided into three groups, according to Le Huec[3].

Group A: normal balance of the spine, the C7 plumb line falls within 3cm of the posterosuperior corner of S1, the pelvic tilt is normal, lower limbs are in complete extension, there is no balance to restore

Group B: compensated balance, the C7 plumb line falls within 3cm of the posterosuperior corner of S1 but the pelvis is retroverted , the lower limbs are in complete extension. In case of surgery for spinal canal decompresion it is advisable to restore the correct lumbar lordosis

Group C: decompensated balance: the C7 plumb line falls usually infront of the posterosuperior corner of S1, the pelvis is retroverted, the hips are extended and the knees are in flexion. This group of patiens are the candidates for spinal balance correction using an osteotomy.

We also used the Oswestry Disability Index (ODI) and the visual analogic scale (VAS) for preoperative evaluation. The preoperative planning was made using two free softwares: Askyphoplan[4] and Surgimap[5], allowing us to determine the level of the osteotomy and the degrees needed for correction.

All the patients from group C were operated according to the status of their deformity, the ones with great sagittal imbalance, where the distance between the C7 Plumb line and the posterosuperior corner of S1 was greater than 10-12 cm were considered ideal candidates for pedicle subtraction osteotomy, it was also used as a revision technique for patients with pre-existing spinal fusions. The Smith-Petersen osteotomy was used for patients with a smaller deformity than described above and witch presented with a mobile disc space anteriorly allowing the opening of the osteotomy. Vertebral column resection which is a major surgery, performed in our study group only in two cases was used for major imbalance cases due to sharp angular thoracic deformity.

The study was approved by Ethical Committee of the Hospital and all the patients signed the informed consent before inclusion in the study.

Surgical technique Each group of patients was operated using only one designated surgical technique. The pedicle subtraction osteotomy, which is a closing wedge osteotomy, is performed with the patient placed prone on the multiflex table, after general endotracheal anesthesia, with the operating table in “flex” position Figure 1, all the surgeries are performed using our surgeon directed neuromonitoring system by motor evoked potentials. We use subperiosteal dissection exposing the posterior elements at the osteotomy level and the vertebras designated for segmentary stabilization, the lateral dissection is carried to the level of the transverse processes. Pedicle screws are inserted at least two levels above and below the osteotomy site, depending on the local conditions. After intraoperative confirmation of the level of osteotomy we resect the transverse processes bilaterally, perform laminectomy and facetectomy, identify the nerve roots and open the pedicle holes. Using the pedicle canal we remove cancellous bone from the vertebral body with curettes. With two osteotomes under intraoperative radiologic evaluation we determine the final angle of the osteotomy Figure 4; the pedicles are removed. The osteotomy is closed by extending the operating table to the “level” position and spinal stability is obtained by connecting the pedicle screws and the rods Figure 2 and 3.

Figure 1. Patient positioning on operating table in “flex” position

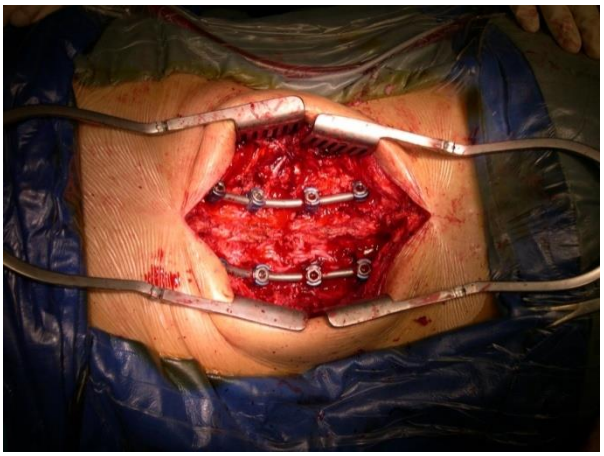

Figure 2 Closed osteotomy site with rods and screws in place

Figure 3 Patient on operative table in "level" positioning

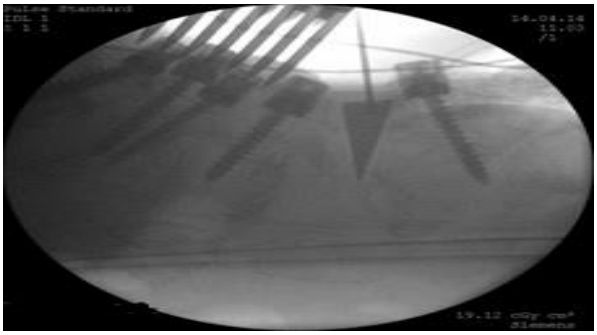

Figure 4 Intraoperative X-ray confirmation of osteotomy angle

The Smith Petersen osteotomy, an opening wedge osteotomy based on the existence of a mobile disc anteriorly, is performed using the same positioning as the pedicle subtraction osteotomy and the same surgical approach. After confirmation of the osteotomy levels and insertion of pedicle screws at least two levels above and below the designated level. The osteotomy removes a posteriori based wedge which includes the spinous processes, the interspinous ligament, the ligamentum flavium, the interlaminar space is also exposed by removing bone with laminectomy rongeus. After identifying the facet joint, a resection at this level is performed, at the desired angle. When extending the operating table to the "level"position the osteotomy is opened anteriorly and the rod-screw system is locked.
We performed the vertebral resection surgeries using the double approach technique, anterior approach by left-sided thoracotomy allowing safe removal of the involved vertebral bodies and the reconstruction with a fiber-mash titanium cage filled with morcelised autograft bone from the resected vertebra; after closing the thoracotomy site a chest tube was left in place allowing good lung expansion[6-13]. The second approach during the same anesthesia allowed to resect the remaining posterior elements of the vertebra and to stabilize the spine using pedicle screws and rods.

Postoperative rehabilitation
All the patients were mobilized in the interval between 24 and 72 hours after surgery, depending on their general health and other associated comorbidities, without any external stabilizing device (orthosis).
Statistical analysis
The independent sample t-test was used for statistical analyses, the mean and standard deviations. $p<0.05$ was considered statistically significant.

RESULTS AND DISCUSSIONS

We obtained a major correction using the pedicle osteotomy technique, with the mean angle obtained at the final follow-up around 34º compared to the mean osteotomy angle obtained in a single level Smith Petersen Osteotomy of about 12º.

		Mean ± SD	p-value
C7 Plumb Line (cm)	Pre-op	18,1±7,8	0,04
	Immediate postop	2,1±3,2	0,03
	Postop	4,2±4,1	0,04
Thoracic Kyphosis Cobb angle T4-T12	Preop	22,1±17,8	0,03
	Immediate postop	30,1±16,2	0,04
	Postop	33,2±17,1	0,03
Lumbar Lordosis Cobb angle L1-S1	Preop	-12,2±19,8	0,03
	Immediate postop	49,3±14,4	0,04
	Postop	47,9±17,5	0,03
P.S.O. ANGLE	Preop	32,3±11,2	0,04
	Immediate postop	33,2±12,3	0,04
	Postop	33,1±14,2	0,04

SD = standard deviation

Table 1. Value of spinal parameters before and after the surgery, their variation in time, for the P.S.O. (pedicle subtraction osteotomy)

We had 4 transitory neurologic postoperative deficits which recovered in the first days after the surgery and one superficial wound infection which needed soft tissue revision surgery and antibiotic treatment; one patient had deterioration of montage in the third day after the surgery, early revision was performed. For the patients in pedicle subtraction osteotomy group, the average blood loss was about 1500ml. In the Smith Petersen Osteotomy group we had 2 neurologic deficits which also recovered in the first days after the surgery. The patients on which the vertebral column resection was performed had the longest postoperative recovery time, due to the double approaches and the existence of the chest tube.

		Mean ± SD	p - value
C7 Plumb Line (cm)	Pre-op	9,4±5,4	0,03
	Immediate postop	2,4±1,5	0,04
	Postop	3,7±2,1	0,03
Thoracic Kyphosis Cobb angle T4-T12	Preop	23,±15,2	0,04
	Immediate postop	27,1±13,1	0,03
	Postop	31,1±15,2	0,03
Lumbar Lordosis Cobb angle L1-S1	Preop	8,1±17,4	0,04
	Immediate postop	23,3±12,2	0,04
	Postop	32,8±12,7	0,04
Smith Petersen osteotomy ANGLE	Preop	12,7±5,9	0,04
	Immediate postop	13,1±7,5	0,03
	Postop	12,2±11,1	0,03

SD = standard deviation

Table 2. Value of spinal parameters before and after the surgery, their variation in time, for the Smith Petersen Osteotomy

The mean Oswestry Disability Index improved from 52,1±12,7 to 29,2±8,9 in the Pedicle Subtraction Osteotomy group and from 42,3±14,1 to 27,8±11,5 in the Smith Petersen Osteotomy group (P=0,04 for both groups).

CASES REPORT

1. L.G. – 77 years old female, multiple surgeries in the thoracolumbar spine, continuous back pain at the presentation in our hospital. Oswestri Disability Index =59

Figure 5 Latero-lateral x-ray before the osteotomy

Figure 6 Anteroposterior preoperative x-ray

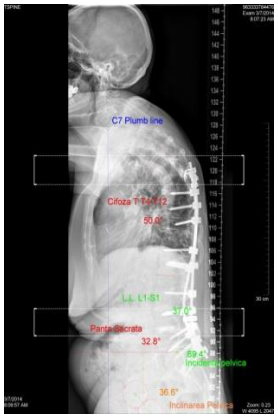

Figure 7 Sagittal Balance Measurements

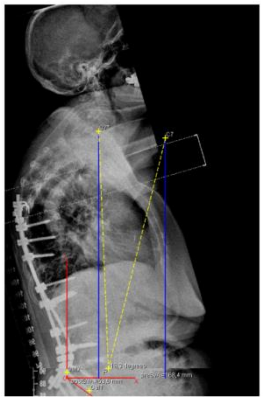

Figure 8 Osteotomy calculations with Askyphoplan software

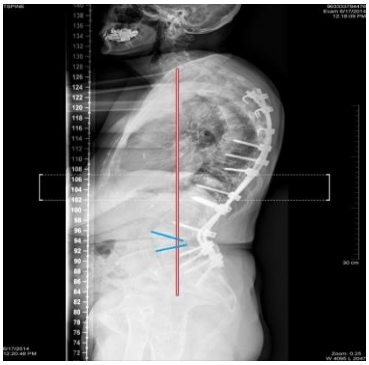

Figure 9 Postoperative result

2. I.V. – 50 years old male; Ankylosing Spondylitis without any therapy; main concern – inability to see the road ahead

Figure 10 and 11 Preoperative status of the patient

Figure 12 Preoperative sagittal balance calculations

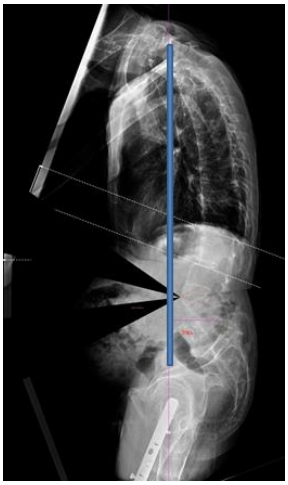

Figure 13 Osteotomy planning with Surgimap software.

Figure 14 Postoperative result

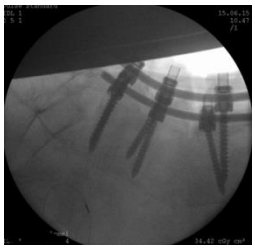

Figure 15 Intraoperative osteotomy level.

CONCLUSIONS

The pedicle subtraction osteotomy is thow a demanding surgical technique offers a good treatment alternative, in selected cases, for restoring the sagittal balance of the spine[14-17]. The surgery can only be performed by an experienced surgical and anestesiological team, the patient will require careful rehabilitation techniques, allowing him to walk freely in a short period after the surgery. In this study we presented our experience with three types of surgical techniques; considering the vertebral column resection an indication for severe cases, the main subject remains the comparison between the subtraction and the Smith Petersen osteotomy. With about 10 degrees of correction per level of Smith-Petersen versus the 30-40 degrees of the subtraction and the ability to be used as a revision surgery in a spine with multiple fused levels we consider the subtraction the most appropriate procedure to be considered in large deformities and revisions.

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