

COMPARISON OF SMITH-PETERSEN, PEDICLE SUBTRACTION OSTEOTOMY AND VERTEBRAL COLUMN RESECTION FOR THE CORRECTION OF SAGITTAL IMBALANCE

COMPARAÇÃO DE RESULTADOS DE OSTEOTOMIAS DE SMITH-PETERSEN, OSTEOTOMIAS DE SUBTRAÇÃO PEDICULAR E VERTEBRECTOMIAS NO TRATAMENTO DO DESEQUILÍBRIO SAGITAL

COMPARACIÓN DE RESULTADOS DE OSTEOTOMÍAS DE SMITH-PETERSEN, OSTEOTOMÍAS DE SUSTRACCIÓN PEDICULAR Y VERTEBRECTOMÍA EN EL TRATAMIENTO DE DESEQUILIBRIO SAGITAL

ANA MARÍA MORALES CODINA¹, JUAN ANTONIO MARTÍN-BENLLOCH¹, DIEGO VALVERDE BELDA¹, SONIA MUÑOZ DONAT¹, CARLOS SÁNCHEZ MONZÓ¹, RAFAEL AGUIRRE GARCÍA¹, MARÍA JESÚS MOLINA AGUILAR¹

ABSTRACT

Objective: To compare the clinical and radiological results of Smith-Petersen osteotomy (SPO), Pedicle Subtraction Osteotomy (PSO) and Vertebral Column Resection (VCR) on sagittal imbalance. **Methods:** Retrospective cohort study. We compared 42 patients submitted to 3 SPO (n=14), 1 PSO (n=16) and 1 VCR (n=12) for fixed sagittal imbalance in the period 2003 to 2011. The sample consisted of 71.4% males, and the mean age was 43 years (17-74). The mean follow-up was 5 years. The complications, results of the SRS-22 questionnaire, sagittal Cobb angle and sagittal vertical axis (SVA) prior to surgery and 2 years after surgery were recorded. **Results:** Mean operating time (min) was lower in SPO vs PSO and VCR (420 ± 347 vs. 578 ± 459 vs. 533 ± 435) (p<0.00). Average blood loss (cc) was lower in SPO vs PSO and VCR (1341 ± 804 vs. 2364 ± 1.459 vs. 2134 ± 1335) (p<0.03). The overall rate of complications was 38%. There were no differences in the mean segmental kyphosis correction achieved, but in the correction of SVA differences were observed, with SPO being lower. In SRS-22, the three groups showed significant differences in all areas, compared with the preoperative results, where there were no differences between the groups. **Conclusions:** there were no differences in complications, although these were more severe in PSO and VCR. No differences were found in correction of segmental kyphosis, but PSO and VSR achieved better results in terms of modifying the SVA. There was no difference in quality of life.

Keywords: Osteotomy; Spine; Spinal curvature; Quality of life.

RESUMO

Objetivo: Comparar os resultados clínicos e radiológicos de pacientes submetidos a osteotomias de Smith-Petersen (SPO), de subtração pedicular (PSO) e vertebrectomias (VCR) em pacientes com desequilíbrio sagital fixo. **Métodos:** Estudo retrospectivo observacional. Foram comparados 42 pacientes submetidos a 3 SPO (n = 14), 1 PSO (n = 16) e 1 VCR (n = 12) por desequilíbrio sagital no período 2003-2011. A amostra é constituída por 71,4% do sexo masculino e a média de idade é de 43 anos (17-74). O tempo médio de acompanhamento foi de 5 anos. Registraram-se as complicações, os resultados do questionário SRS-22, ângulos de cifose e SVA no pré-operatório e no pós-operatório, aos 2 anos. **Resultados:** O tempo de cirurgia (minutos) foi menor em SPO comparado com PSO e VCR (420 ± 347 vs. 578 ± 459 vs. 533 ± 435) (p < 0,00). As perdas sanguíneas intraoperatórias (cc) foram menores em SPO quando comparadas com PSO e VCR (1341 ± 804 vs. 2364 ± 1.459 vs. 2134 ± 1335) (p < 0,03). Do total, 38% apresentaram complicações. Não houve diferenças na correção média da cifose segmentar, mas sim na correção SVA, sendo menor SPO. No SRS-22, os três grupos apresentaram mudanças significativas em todas as áreas, em comparação com o pré-operatório, sem diferenças significativas entre os grupos. **Conclusões:** Não houve diferenças nas complicações, embora tenham sido mais graves em PSO e VCR. Não se verificaram diferenças na correção da cifose segmentar, mas PSO e VCR obtiveram melhores resultados na modificação do SVA. Não havia diferenças na qualidade de vida.

Descritores: Osteotomia; Coluna vertebral; Curvaturas da coluna vertebral; Qualidade de vida.

RESUMEN

Objetivo: Comparar los resultados clínicos y radiológicos de pacientes sometidos a osteotomías de Smith-Petersen (SPO), de sustracción pedicular (PSO) y vertebrectomías (VCR) en pacientes con desequilibrio sagital. **Métodos:** Estudio observacional y retrospectivo. Se compararon 42 pacientes sometidos a 3 SPO (n=14), 1 PSO (n=16) y 1 VCR (n=12) por desequilibrio sagital fijo en el período de 2003-2011. La muestra constó de 71,4% de hombres y la edad promedio fue 43 años (17-74). El tiempo de seguimiento promedio fue 5 años. Se registraron las complicaciones, los resultados del cuestionario SRS-22, el ángulo de cifosis y eje sagital vertical (SVA) en el preoperatorio y a los 2 años postoperatorios. **Resultados:** El tiempo quirúrgico (min.) fue menor en SPO respecto a PSO y VCR (420±347 vs. 578±459 vs. 533±435) (p<0,00). El sangrado intraoperatorio (cc) fue menor en SPO respecto a PSO y VCR (1341±804 vs. 2364±1459 vs. 2134±1335) (p<0,03). Del total, 38% presentaron complicaciones. No se observaron diferencias en el promedio de corrección en la cifosis segmentaria, pero sí en la corrección del SVA, siendo menor SPO. En el SRS-22, en los tres grupos se presentaron cambios significativos en todos los dominios respecto al preoperatorio, sin diferencias significativas entre grupos. **Conclusiones:** No se encontraron diferencias en las complicaciones, aunque fueron de mayor gravedad en PSO y VCR. No había diferencias en la corrección de la cifosis segmentaria, pero PSO y VCR obtuvieron mejores resultados en la modificación del SVA. No había diferencias en la calidad de vida.

Descriptores: Osteotomía; Columna vertebral; Curvaturas de la columna vertebral; Calidad de vida.

1. Hospital Universitario Doctor Peset Aleixandre, Valencia, Spain.

Study conducted at the Hospital Universitario Doctor Peset Aleixandre, Valencia, Spain.
Correspondence: Hospital Universitario Doctor Peset Aleixandre, Valencia, Spain. 40768amc@gmail.com

INTRODUCTION

Imbalance in the sagittal plane results in significant disability for the subject in terms of quality of life. To correct this balance, formulas have been developed using spinal and pelvic parameters in the preoperative planning¹⁻³ according to those who perform the procedures.

Multiple techniques have been described for the correction of fixed sagittal imbalance. These include Smith-Petersen osteotomy (SPO), pedicle subtraction osteotomy (PSO), and vertebral column resection (VCR), among others. It is generally acknowledged that an SPO can correct 10° per segment, a PSO 35°, and a VCR 40° or more, each method having different complications and clinical outcomes.^{4,5} However, we have found no published studies that compare the results of the three procedures.

The objective of this study is to compare the clinical and radiological findings of three types of osteotomies in patients with fixed sagittal imbalance.

MATERIAL AND METHODS

We conducted an observational, retrospective study of 42 patients operated on for fixed sagittal imbalance in the period 2003 to 2011 by the same principal surgeon.

We analyzed three groups of patients: those submitted to three SPOs, one a PSO and one a VCR.

Data were collected through a review of the clinical history and radiological analysis by the first author of the article.

Demographic data were collected, and also data on the type of surgery, levels of fusion, localization of the osteotomy, surgical time, intraoperative bleeding, estimated number of days in the postanesthesia care unit (PACU), and any complications. All the patients filled out the SRS-22 questionnaire before surgery, and 2 years after surgery.

The radiological measurements were taken before the surgery and 2 years after surgery. A simple X-ray was used to measure the segmental angle of kyphosis at the site of the osteotomy, taking as reference the vertebral disc above the osteotomy and the vertebral disc below it. The same was done in the group of 3 SPOs, but in the vertebrae above and below the three contiguous osteotomies. Measurements of sagittal balance were taken in a lateral teleradiography of the entire spine, with the patient in the standing position. We measured the distance between the plumb line of C7 and the posterior superior edge of disc S1 (sagittal vertical axis, SVA).

RESULTS

The sample comprised a total of 42 patients: 14 were submitted to three SPOs, 16 to one PSO and 12 to one VCR.

The sample included 71.4% men, and the average age was 43 years (range: 17-74 years). The three groups did not show any statistically significant differences in terms of sex, age or number of comorbidities. (Table 1)

The median follow-up time was 5 years (range: 2-10).

Table 2 shows the etiologies of the sagittal imbalance of the patients in our sample.

The majority of the SPOs were located between T7 and T11; the PSO and the VCR in T12.

Levels of fusion in the patients submitted to VCR were lower than those in the patients submitted to SPO and PSO, with a statistically significant difference. VCR 5.33 ± 0.651 vs SPO 8.43 ± 1.342 vs 7.31 PSO ± 2.120 (p=0.03).

Table 3 shows the radiological measurements in the results, with no statistically significant differences being found in the segmental

Table 1. Demographic data.

	SPO (n=14)	PSO (n=16)	VCR (n=12)	p
Age (Years)	52.2 ± 48.3	48.2 ± 43.3	48.2 ± 43.3	0.20
Sex (% men)	71.42	75	66.67	0.17
Number of comorbidities	2.3±2.4	2.6±2.8	2.0±1.8	0.43

SPO (Smith-Petersen osteotomy); PSO (pedicle subtraction osteotomy); VCR (vertebral column resection).

angle of kyphosis between the three groups. However, the modification of SVA is significantly lower in SPO. The mean surgery times, intraoperative blood loss and estimated length of time in the PACU were lower in the SPO patients than in the PSO and VCR patients, with statistically significant differences. (Table 4)

Thirty-eight percent of patients presented complications (16 out of 42 patients). Table 5 shows these data by group.

Table 6 shows the results of the clinical assessment using the SRS-22 questionnaire. It is observed that in the preoperative and 2 years postoperative, there are no statistically significant differences in the scores in the different domains. However, the changes between the two times are statistically significant, with the scores improving in all the domains in the postoperative period.

Table 2. Etiology.

	SPO (n=14)	PSO (n=16)	VCR (n=12)
Sequelae of fracture	2	8	10
Adult degenerative kyphoscoliosis	5	4	0
Adolescent idiopathic scoliosis	1	0	0
Congenital kyphoscoliosis	0	0	1
Scheuermann's Disease	2	0	0
Adult chest hyperkyphosis	1	0	0
Angular kyphosis adjacent to instrumentation	3	2	1
Kyphosis (ankylosing spondylitis)	0	2	0

SPO (Smith-Petersen osteotomy); PSO (pedicle subtraction osteotomy); VCR (vertebral column resection).

Table 3. Radiological measurements: preoperative and 2 years postoperative.

	Average correction kyphosis (°)	Preoperative SVA (cm)	Postoperative SVA (cm)	Average correction SVA (cm)
SPO (n=14)	36.6 ± 34.5	4.83 ± 3.20	0.88 ± 0.42	3.95
PSO (n=16)	37.9 ± 34.5	13.4 ± 11.0	5.10 ± 4.34	8.30
VCR (n=12)	45.6 ± 40.5	13.0 ± 12.3	4.67 ± 4.21	8.33
P	0.10			0.007

SVA (vertical axis sagittal); SPO (Smith-Petersen osteotomy); PSO (pedicle subtraction osteotomy); VCR (vertebral column resection).

Table 4. Loss of blood, surgical time, length of stay in the PACU.

	SPO (n=14)	PSO (n=16)	VCR (n=12)	p
Intraoperative blood loss (cc)	1341 ± 804	2364 ± 1459	2134 ± 1335	0.03
Surgery time (minutes)	420 ± 347	578 ± 459	533 ± 435	0.00
Length of time in the PACU (days)	1.8 ± 1.2	2.9 ± 2.1	3.1 ± 2.6	0.00

SPO (Smith-Petersen osteotomy); PSO (pedicle subtraction osteotomy); VCR (vertebral column resection).

Table 5. Complications.

	SPO (n=14)	PSO (n=16)	VCR (n=12)
Pseudoarthrosis	3	5	3
Radiculalgia	3	1	2
Superficial infection	1	2	1
Deep infection	0	1	0
Spondylodiscitis	0	1	0
Septic shock	0	1	0
Death (pancreatitis)	0	1	0
Epidural hematoma	0	0	1
Subcutaneous emphysema	1	0	0
Pleural effusion	2	0	0
Dural injury	0	1	1
Non-traumatic fractures	0	2	0
Deep vein thrombosis	1	0	2
Postoperative neurologic deficit	0	0	0

SPO (Smith-Petersen osteotomy); PSO (pedicle subtraction osteotomy); VCR (vertebral column resection).

DISCUSSION

In our series, the corrections of the segmental kyphotic angle were similar to those found in the study of Cho et al.,⁶ who compared patients submitted to three or more SPOs with those submitted to one PSO for sagittal imbalance. They found an angle of correction of segmental kyphosis of 33.0° ± 9.2° and in the group subjected to SPO, this angle was 31.7° ± 9.0°. Our results were somewhat better, but without significant differences: 36.6° ± 34.5° in those submitted to three SPOs, 37.9° ± 34.5 in those submitted to PSO and

Table 6. Results of SRS-22 questionnaire.

	SPO (n=14)	PSO (n=16)	VCR (n=12)	p
Preoperative				
Function/Activity	2.6 ± 1.0	3.0 ± 0.9	3.1 ± 0.7	0.13
Pain	2.8 ± 0.9	2.2 ± 0.7	2.9 ± 1.0	0.20
Self image	3.0 ± 1.1	2.6 ± 0.8	2.8 ± 0.6	0.23
Mental health	3.2 ± 0.7	2.7 ± 0.5	2.2 ± 0.5	0.17
Satisfaction	2.5 ± 0.6	2.6 ± 0.3	2.8 ± 0.7	0.39
End				
Function/Activity	3.8 ± 0.8	4.2 ± 0.9	4.0 ± 0.7	0.29
Pain	3.9 ± 0.4	3.4 ± 0.6	3.2 ± 0.8	0.25
Self image	4.2 ± 1.0	3.7 ± 0.5	4.0 ± 0.8	0.17
Mental health	4.3 ± 0.8	4.0 ± 0.6	3.9 ± 0.6	0.20
Satisfaction	4.0 ± 0.8	3.9 ± 0.7	4.1 ± 0.8	0.28
Change (p preoperative vs. final)				
Function/Activity	<0.05	<0.05	<0.05	
Pain	<0.05	<0.05	<0.05	
Self image	<0.05	<0.05	<0.05	
Mental health	<0.05	<0.05	<0.05	
Satisfaction	<0.05	<0.05	<0.05	

SPO (Smith-Petersen osteotomy); PSO (pedicle subtraction osteotomy); VCR (vertebral column resection).

45.6° ± 40.5 in those submitted to VCR (p=0.10), which indicates that the corrections of segmental kyphosis achieved with three SPOs, one PSO and one VCR are the same.

In terms of SVA, the patients submitted to three SPOs showed a smaller degree of SVA correction - 3.95 cm compared to 8.30 cm in the PSO and 8.33 cm in the VCR (p=0.007). However, the average preoperative SLA measurements were greater in the PSO and VCR groups (13.4 and 13.0 cm) than the SPO group (4.83 cm), therefore the groups are not comparable.

The most frequent complication in our sample in the three groups was pseudoarthrosis, especially in the PSO group. The second most frequent complication was radiculalgia. (Table 6)

In regard to pseudoarthrosis, the study of Cho et al.⁶ observed three cases of pseudoarthrosis out of 30 in the SPO group.⁶ This figure contrasts with that of our sample: 3 out of 14 cases. Meanwhile, the PSO group had the highest percentage of pseudoarthrosis at two years postoperative (31.3 %). None occurred at the site of the osteotomy and all were proximal to the instrumentation. Our percentage of pseudoarthrosis is higher than in previous studies, such as that of Kim et al.,⁷ which evaluated the long-term results (5 years) of PSO carried out at the lumbar level, with a result of 22.9%. In relation to VCR, our study found 25% pseudoarthrosis (3 out of 12 cases). This contrasts with previous studies that found low percentages in patients submitted to VCR, with rates of 0%.^{5,8}

In our study, the loss of blood was greater in VCR and PSO. This is not due to age differences between groups, or to the number of fusion levels (higher in SPO and PSO than in VCR), but to the increased time and complexity of the surgery.

In relation to infection, our sample shows 14.29% of infections. In the PSO group, there was one case of spondylodiscitis and another of deep infection. The latter was a patient who had pancreatitis in the postoperative period (presumably as a result of low blood pressure during surgery), septic shock and death. The sample is not large enough to be able to test the statistical significance in this case, but there appears to be no difference between the groups. The study of Pull et al.⁹ shows that the VCR group (11.1%) has an increased risk

of infection with regard to PSO, SPO, VCR and ASO (osteotomy by the anterior approach) (4.1% of the remainder), with obesity being determined as the main risk factor for the development of infection.

In our sample there were no postoperative neurological complications. Previous studies have established variable rates of complications. A study by Buchowski et al.¹⁰ shows 11.1% neurological complications (2.8% permanent) in PSO. In VCR, the group of Suk et al.⁵ showed 17% neurological complications. A study by Cho et al.⁶ found 30 cases in patients subjected to more than 2 SPOs.

In our series, we found two cases of non-traumatic compression fractures of L5 (in the last instrumented vertebra) in PSO in the immediate postoperative period. The two cases were long instrumentations that were completed at that level, and required subsequent surgery with extension of the instrumentation to the iliac crests. (Figure 1 A-B)

In terms of clinical outcomes measured with the SRS-22 questionnaire, the three types of osteotomies produced similar clinical results, with no significant differences between the groups.

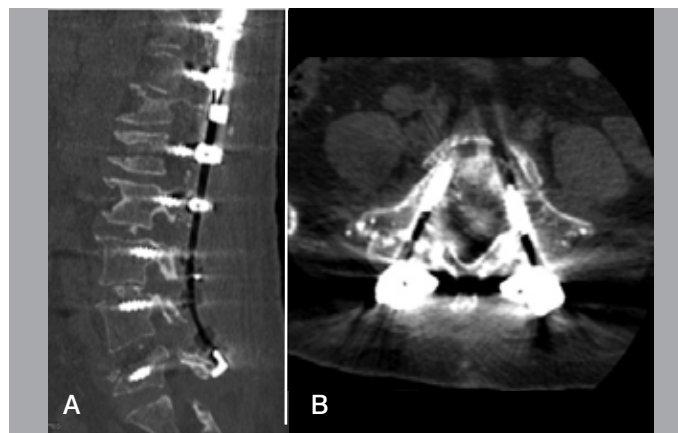


Figure 1. Non-traumatic compression fracture of L5.

CONCLUSIONS

Comparing groups of patients submitted to three SPOs, one PSO and one VCR, we found no differences in the correction of segmental kyphosis, but we did find differences in the sagittal balance (SVA). It was not possible to make comparisons between three SPOs, PSO and VCR based on the smaller preoperative SVA.

In terms of complications, no differences were found, but the most serious ones occurred in PSO and VCR, with pseudoarthrosis being the most common complication.

There were no significant differences in terms of quality of life between groups, but there were significant changes between the preoperative and postoperative in terms of clinical improvement, with no differences between the groups.

All authors declare no potential conflict of interest concerning this article.

REFERENCES

- Boulay C, Tardieu C, Hecquet J, Benaim C, Mouilleseaux B, Marty C, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: standard values and prediction of lordosis. *Eur Spine J.* 2006;15(4):415-22
- Kim YJ, Bridwell KH, Lenke LG, Rhim S, Cheh G. An analysis of sagittal spinal alignment following long adult lumbar instrumentation and fusion to L5 or S1: can we predict ideal lumbar lordosis? *Spine (Phila Pa 1976).* 2006;31(20):2343-52.
- Lafage V, Schwab F, Vira S, Patel A, Ungar B, Farcy JP. Spino-pelvic parameters after surgery can be predicted: a preliminary formula and validation of standing alignment. *Spine (Phila Pa 1976).* 2011;36(13):1037-45.
- Bridwell KH. Decision making regarding Smith-Petersen vs. pedicle subtraction osteotomy vs. vertebral column resection for spinal deformity. *Spine (Phila Pa 1976).* 2006;31 (Suppl 19):S171-8.
- Suk SI, Chung ER, Kim JH, Kim SS, Lee JS, Choi WK. Posterior vertebral column resection for severe rigid scoliosis. *Spine (Phila Pa 1976).* 2005;30(14):1682-7.
- Cho KJ, Bridwell KH, Lenke LG, Berra A, Baldus C. Comparison of Smith-Petersen versus pedicle subtraction osteotomy for the correction of fixed sagittal imbalance. *Spine (Phila Pa 1976).* 2005;30(18):2030-7.
- Kim YJ, Bridwell KH, Lenke LG, Cheh G, Baldus C. Results of lumbar pedicle subtraction osteotomies for fixed sagittal imbalance: a minimum 5-year follow-up study. *Spine (Phila Pa 1976).* 2007;32(20):2189-97.
- Auerbach JD, Lenke LG, Bridwell KH, Sehn JK, Milby AH, Bumpass D, et al. Major complications and comparison between 3-column osteotomy techniques in 105 consecutive spinal deformity procedures. *Spine (Phila Pa 1976).* 2012;37(14):1198-210.
- Pull ter Gunne AF, van Laarhoven CJ, Cohen DB. Surgical site infection after osteotomy of the adult spine: does type of osteotomy matter? *Spine J.* 2010;10(5):410-6.
- Buchowski JM, Bridwell KH, Lenke LG, Kuhns CA, Lehman RA Jr, Kim YJ, et al. Neurologic complications of lumbar pedicle subtraction osteotomy: a 10-year assessment. *Spine (Phila Pa 1976).* 2007;32(20):2245-52.