



# Impact of pedicle subtraction osteotomy on health-related quality of life (HRQOL) measures in patients undergoing surgery for adult spinal deformity: a systematic review and meta-analysis

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## Abstract

**Study design** Systematic review and meta-analysis.

**Background** Three-column osteotomies (3-CO) have gained popularity in the last decade as part of the armamentarium for the surgical correction of sagittal imbalance in patients with adult spinal deformity (ASD). Three-column osteotomies in the form of pedicle subtraction osteotomy (PSO) may be necessary to achieve adequate correction for severe and rigid spinal deformity. Studies reporting improvement in health-related quality of life (HRQOL) with validated outcome measures after PSO surgery are sparse and currently consist of small series.

**Objective** Evaluate the improvement in HRQOL measures following PSO for adult spinal deformity.

**Methods** Two independent reviewers conducted a systematic review of the English literature between period 1996 and 2019 for articles reporting outcome of PSO in patients with ASD according to PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines. Inclusion criteria were studies consisting of patient-reported outcome Oswestry Disability Index (ODI) and Scoliosis Research Society 22 or 24 (SRS) outcomes after PSO surgery for adult spine deformity patients (18 years or older) with a minimum follow-up of 1 year.

**Results** Eight studies with 431 PSOs were included in the meta-analysis. The results showed a statistically significant improvement in ODI in PSO ( $P < 0.0001$ ), and the mean clinically important difference was achieved with both ODI (50.46 (45.5–55.4) preoperatively to 32.78 (29.7–39) postoperatively) and SRS (2.49 (2.38–2.7) preoperatively to 3.26 (2.8–4.1) postoperatively) scores.

**Conclusion** This meta-analysis did find improvements in the health-related quality of life in patients undergoing PSO surgery for adult spinal deformity.

**Keywords** Pedicle subtraction osteotomy · Health-related quality of life · Adult spine deformity · Oswestry Disability Index (ODI) · Scoliosis research society (SRS)

## Introduction

Sagittal plane spinal deformity has been increasingly recognized to adversely affect health-related quality of life. It is commonly linked to adult spinal deformity and to other etiologies such as post-traumatic kyphosis and iatrogenic flat back after lumbar fusion [1, 2]. The goals of spinal

deformity surgery in adults are to alleviate pain, prevent deformity progression and improve function [3].

Rigid adult spinal deformity may be surgically corrected with three-column osteotomy (3-CO) techniques such as pedicle subtraction osteotomy (PSO) and vertebral column resection (VCR) which involve cuts from the posterior column extending into the anterior column, or anterior half of the vertebral body, and are thus considered three-column osteotomies [4–6]. Despite the various permutations in techniques, three-column osteotomies allow for a significant correction of rigid spinal deformity in the sagittal, coronal and axial planes simultaneously through a posterior-only approach [4–9].

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In 1985, Thomassen [10] first described the three-column posterior wedge osteotomy for the management of fixed sagittal deformities in patients with ankylosing spondylitis. Pedicle subtraction osteotomy is described as a V-shaped wedge resection of the vertebral body including both pedicles and posterior elements that is often performed for the treatment for idiopathic or iatrogenic flat back deformity with sagittal imbalance [10, 11]. It is a powerful surgical technique and can usually produce between 30 to 40 degrees of lordosis at each level [12, 13].

The purpose of this study was to evaluate improvement in health-related quality of life measures following PSO for adult spinal deformity at a minimum of 1-year follow-up.

## Methods

### Search strategy

Several databases such as the Cochrane library, PubMed and EMBASE were systematically searched to identify potentially eligible articles. All the above databases were searched up to late 2019. The search strategy was based on the combination of the following keywords: three-column osteotomy, pedicle subtraction osteotomy, adult spine deformity and health-related quality of life measures. The reference list of selected literatures was also reviewed.

### Inclusion and exclusion criteria

Inclusion criteria were established before the search, and the following criteria were used:

Studies were included if they reported the outcomes (ODI and/or SRS-22/24) after PSO surgery for adult spine deformity patients (18 years or older) with a minimum follow-up of 1 year. Figure 1 is a case illustration from our unit.

Studies were excluded if the follow-up period was less than 1 year, pediatric deformity studies and those without any outcome measures.

### Data extraction

All potentially eligible studies were obtained as full articles. Two reviewers independently assessed the studies for the predetermined inclusion and exclusion criteria. Controversial studies were discussed by the two reviewers to reach consensus. Information extracted on each eligible study included the first author, year of publication, type of study, level of evidence, patient characteristics, number of patients and type of osteotomy used.

Review was conducted according to PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines using a PRISMA checklist [14].



**Fig. 1** **a** Whole spine sagittal image and **b** coronal pre- and postoperative images showing the significant correction of a degenerative kyphoscoliosis deformity in 73-year-old female patient who underwent a L4 PSO and T10-pelvis fusion

## Statistical analysis

STATA software version 13 was used for meta-analysis. The odds ratio (OR) and the 95% confidence intervals (CI) were calculated for clinical outcome assessments. The level of significance was set at  $P < 0.05$ . Heterogeneity was evaluated by  $I^2$ -statistics and  $\chi^2$  test. If heterogeneity was significant ( $I^2 > 50\%$  and  $P < 0.10$ ), the random-effects model was used. Alternately, the fixed-effects model was used. A Forest plot was generated.

## Patient clinical outcomes

Scoliosis Research Society (SRS22/24) clinical outcome and the Oswestry Disability Index (ODI) were used to evaluate patient outcomes at final follow-up.

## Results

### Study inclusion and characteristic

Summary of the identification and selection process of the study is shown in Fig. 2. After reviewing the titles, the abstracts and the full texts, we identified eight published studies that met all our inclusion criteria [2, 4, 8, 11, 15, 16, 17 and 18]. The characteristics of the included studies are summarized in Table 1.

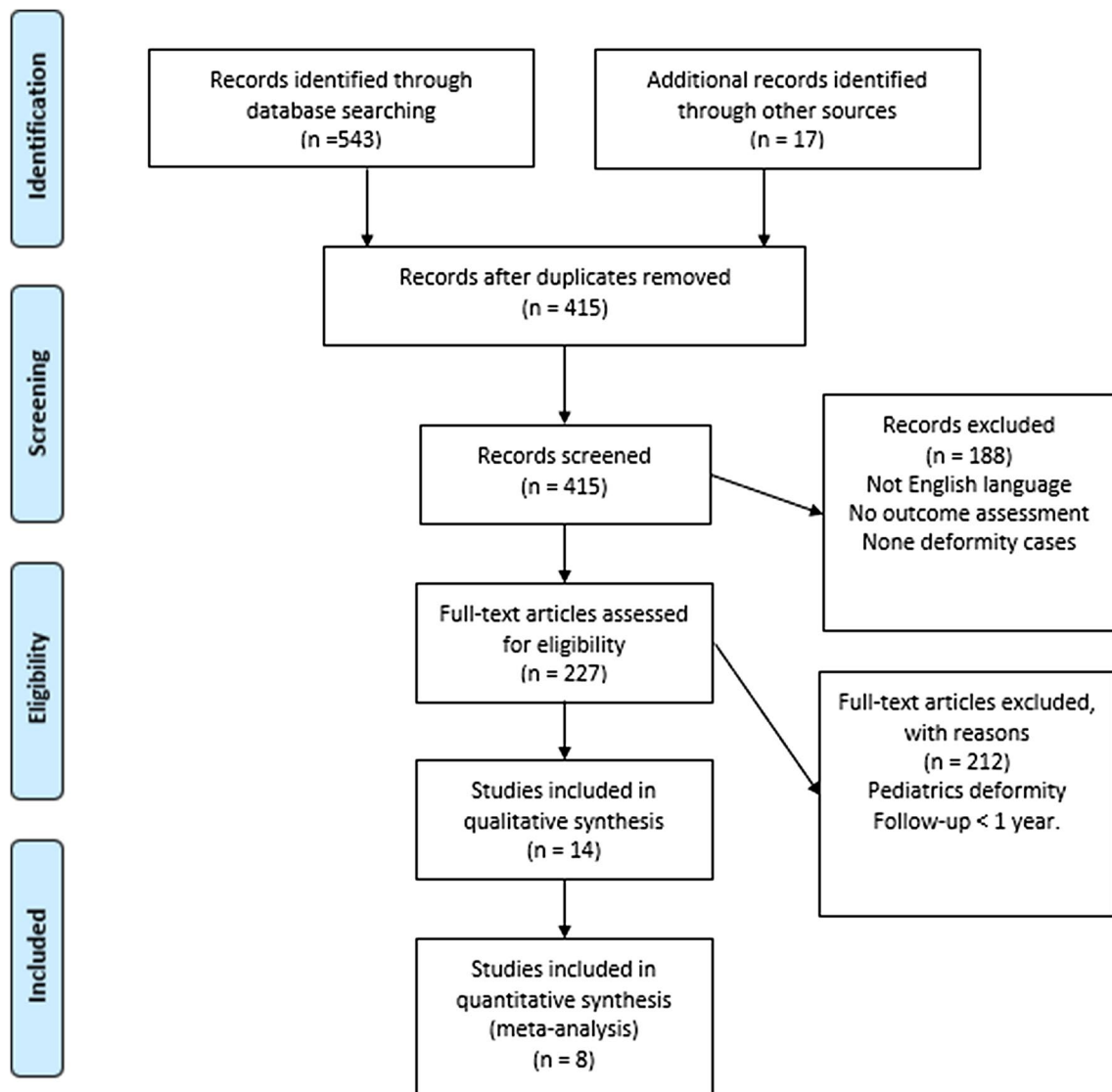


Fig. 2 Flowchart of literature selection

**Table 1** Results of a systematic review of health-related quality of life measures in pedicle subtraction osteotomy

Author, year	Study design	Level of evidence	Number of patients	Surgical procedure	Outcome			
					ODI		SRS	
					Pre-op	Follow-up	Pre-op	Follow-up
Eskilsson [2]	Retrospective study	III	90	PSO	55	39	-	-
Bridewell [4]	Prospective:outcomes Retrospective: radio-graphic analysis	III	29	PSO	52.66	34.21	-	-
Cho [8]	Prospective: Clinical data Retrospective: radio-graphic analysis	III	41	PSO	47.9±15.8	29.7±18.3	-	-
Auerbach [11]	Retrospective study	III	87	PSO	-	-	2.4±0.7	4.1±1.0
Rose [15]	Retrospective study	III	40	PSO	45.5±18	29.8±17	Percentage	Percentage
Hyun [16]	Prospective: outcomes Retrospective: clinical data	III	10	PSO	55.4±13.6	30.2±16.5	-	-
Fakurnejad [17]	Retrospective study	III	94	PSO	46.3±18.3	33.8±17.8	2.7±0.7	2.9±0.7
Choi [18]	Retrospective case series	III	40	PSO	-	-	2.38±0.73	2.80±0.81

PSO pedicle subtraction osteotomy, ODI Oswestry Disability Index, SRS Scoliosis Research Society

## Meta-analysis results

### Pedicle subtraction osteotomy and ODI scores

Six articles studied ODI outcomes in PSO surgery [2, 4, 8, 15, 16, 17]. The total number of patients was 304 patients with a minimum follow-up of 1 year. The findings of these studies were pooled using a meta-analysis [Fig. 3]. *The results showed statistically significant improvement in ODI in patients undergoing PSO surgery ( $P < 0.0001$ ): from 50.46 (45.5–55.4) preoperatively to 32.78 (29.7–39) postoperatively.*

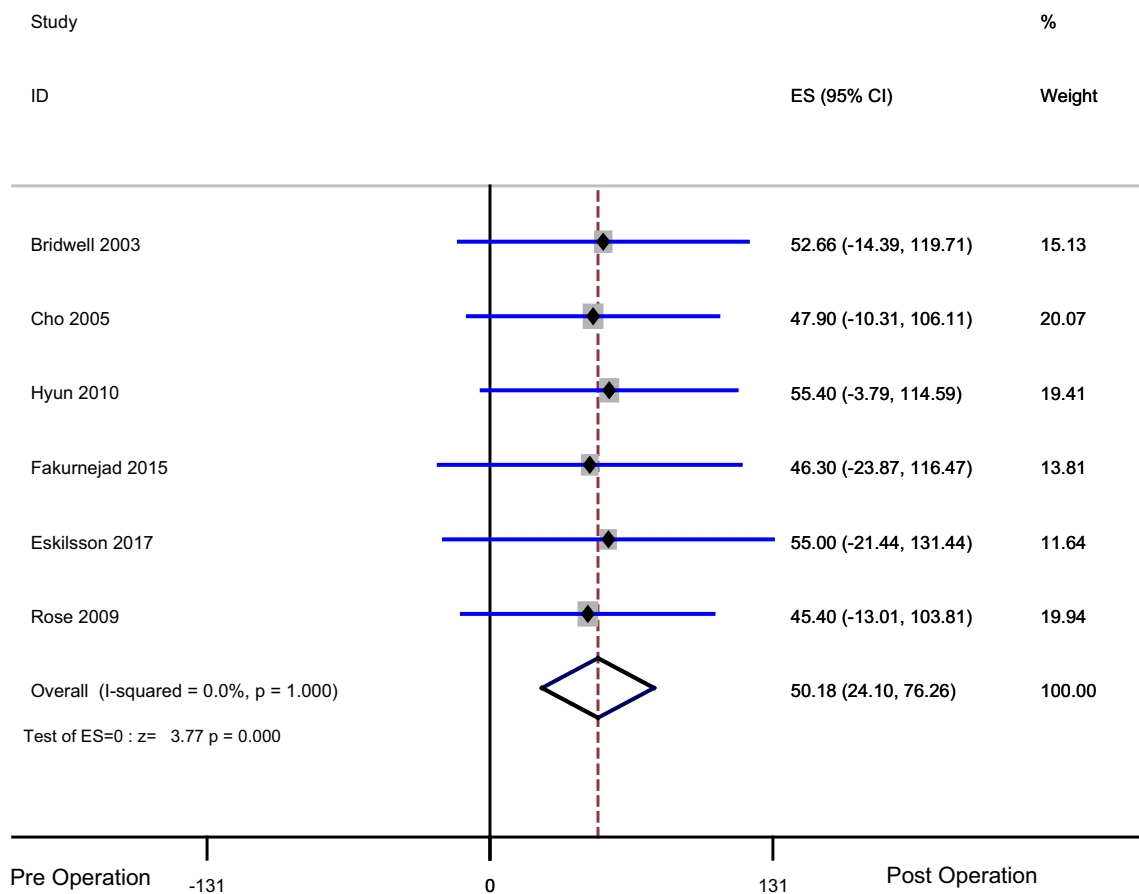
### Pedicle subtraction osteotomy and SRS scores

Three articles studied the SRS outcome in PSO surgery [11, 17, 18]. The total number of patients was 221 patients with a minimum follow-up of 1 year. The findings of these studies were pooled using a meta-analysis [Fig. 4]. *The results showed a nonsignificant improvement in SRS scores in patients undergoing PSO surgery ( $P = 0.997$ ): from 2.49 (2.38–2.7) preoperatively to 3.26 (2.8–4.1) postoperatively.*

## Discussion

In the present systematic review, eight studies with total of 431 patients who underwent PSOs for adult spinal deformity were included. It was found that PSO surgery did significantly improve the health-related quality of life (significantly with regard to the ODI scores). Three articles studied SRS scores after PSO surgery [11, 17, 18], two of which [11, 17] reported significant improvement in SRS outcome following PSO surgery.

Three-column osteotomies are powerful tools for addressing fixed, rigid deformities. They are technically challenging and are associated with significant morbidity rates. This technique allows for significant correction of rigid spinal deformities in the sagittal, coronal and axial planes simultaneously through a posterior-only approach [4, 11, 19]. Schwab has classified the grades of osteotomies with a vertebral column resection (VCR) as the most aggressive for the treatment for severe and rigid spinal deformities [7]. Fakurnejad et al. [17] reported statistically significant improvement in ODI ( $P < 0.05$ ) and SRS ( $P < 0.05$ ) after VCR surgery. Similarly, Auerbach et al. [11] reported statistically significant improvement in SRS ( $P < 0.001$ ) after VCR for ASD. Hassanzadeh et al. [3] and Pratali et al. [20] both studied the ODI and SRS outcomes in 3-CO without specifying the type of osteotomy surgery. Their results showed statistically significant improvement in both measures with a minimum follow-up of 1 year.



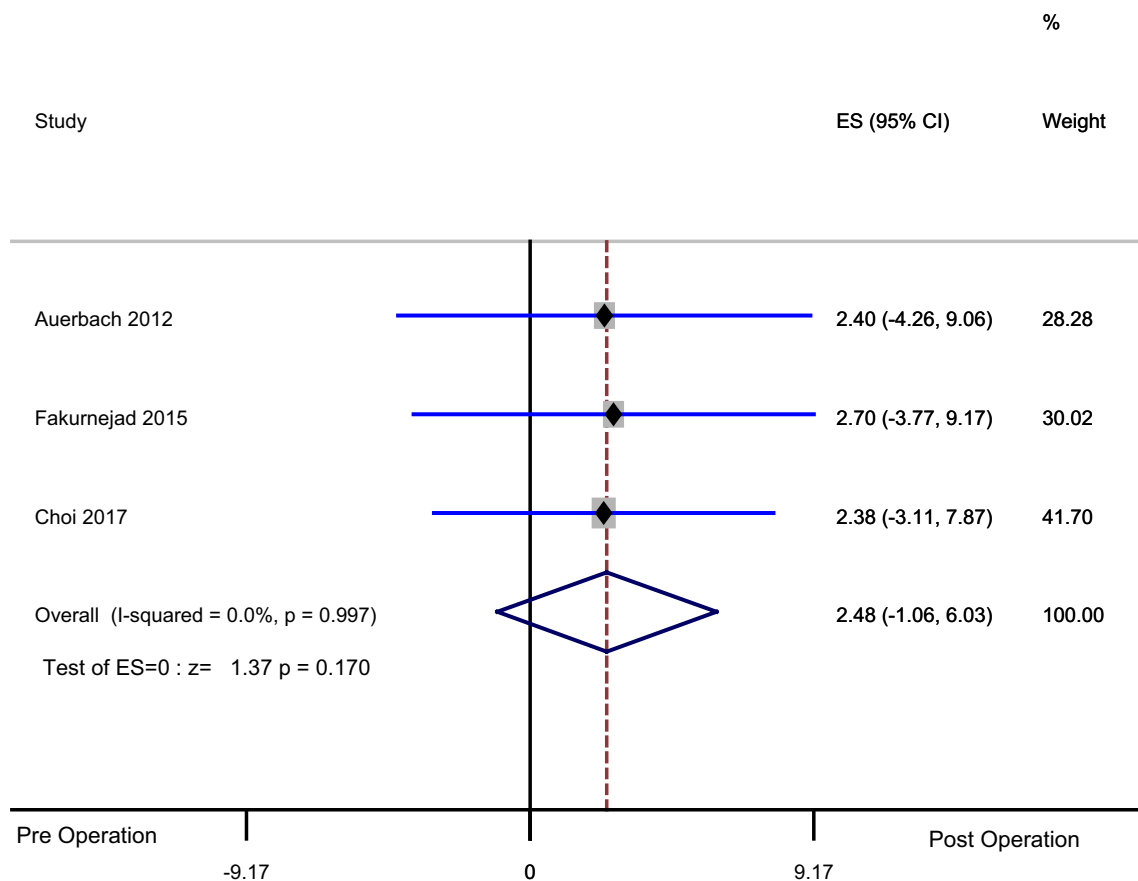
**Fig. 3** Forest plot of ODI outcome in PSO

There have been a few studies looking at the ‘mean clinically significant difference’ (MCID) with the quality of life and outcome scores [21]. Park et al. [22] studied outcome measures like ODI and visual analog scale (VAS) in patients who underwent ASD surgery. In relation to ODI, MCID was defined as a positive change of 12.8 which was achieved by 64.3% of their patients. In our meta-analysis, the ODI score improved significantly ( $P < 0.0001$ ) by 17.68 and so reached the MCID of 12.8 [22]. Crawford III et al. [23] studied MCID threshold values for SRS-22R domains in patients with adult spinal deformity undergoing surgical correction. They concluded that MCID for SRS-22 scores could be estimated as 0.4, which corresponded to a change of one interval in two of the five questions for a single domain. With this threshold in mind, the difference in our SRS scores was 0.77 and thus also reached the MCID, even though not statistically significant.

Given the complexity and technical demands associated with such osteotomy techniques, the risk of complications remains high [24]. Prior studies have endorsed complication rates as high as 70% [25, 26]. Furthermore, approximately

15–20% of ASD patients may also require reoperation [27] and the mortality rate postoperatively ranges from 0.03% to 3.52% [28, 29]. While predictors of morbidity after ASD surgery have been well studied, less is known about the independent predictors of mortality [30]. Zuckerman et al. [30] reported minor and major factors associated with all-cause mortality in 1 year following ASD surgery. Minor factors were related to surgical site infection, pneumonia and urinary tract infection, whereas major factors included deep vein thrombosis, acute kidney injury, requiring ventilation for more than 48 hours, unplanned intubation, sepsis, pulmonary embolism, stroke and myocardial infarction.

It is perhaps not surprising then that there is renewed interest in anterior (including direct lateral and antero-lateral) column realignment procedures, which lengthen the anterior column and may be combined with a posteriorly based osteotomy to further increase the lordosis [31, 32]. A recent study found similar radiographic results when compared to PSO for correction sagittal plane deformity [33]. These approaches, however, have their unique complications, primarily related to their modes of spinal access [34].



**Fig. 4** Forest plot of SRS outcome in PSO

It must therefore be acknowledged that these improvements in HRQOL surgery after a PSO come at the expense of a high complication rate. A limitation of our study is of course the level of evidence for the available literature (level III). Future research is needed with long-term follow-up to clearly identify the effect of PSO in health-related quality of life measures.

## Conclusion

Pedicle subtraction osteotomy significantly improves the health-related quality of life as measured by the ODI in patients with adult spinal deformity.

## Compliance with ethical standards

**Conflict of interest** None of the authors has any potential conflict of interest.

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