



Indirect foraminal decompression and improvement in the lumbar alignment after percutaneous cement discectomy

Laszlo Kiss^{1,2,3} · Peter Pal Varga¹ · Zsolt Szoverfi^{1,4} · Gabor Jakab¹ · Peter Endre Eltes^{1,2,3} · Aron Lazary^{1,4}

Received: 22 June 2018 / Revised: 17 February 2019 / Accepted: 28 March 2019 / Published online: 20 April 2019
© Springer-Verlag GmbH Germany, part of Springer Nature 2019

Abstract

Purpose Percutaneous cement discectomy (PCD) is a minimally invasive surgical procedure, that can provide a segmental stabilizing and indirect decompression effect in case of severely degenerated discs characterized by vacuum phenomenon. The objective of this study was to evaluate the effects of PCD on spinopelvic radiological parameters and their associations with the clinical outcome.

Methods Retrospective analysis of prospectively collected dataset of 28 patients (112 lumbar segments) who underwent single- or multilevel PCD was performed. Spinopelvic, intrasegmental and intersegmental parameters were measured on lumbar X-rays pre-, postoperatively and 6 months after the surgery. Correlations between radiological parameters and clinical outcome data were determined.

Results Sacral slope significantly increased ($p < .001$), and pelvic tilt ($p < .05$) was decreased after the PCD procedure. Segmental and total lordosis ($p < .05$, $p < .05$) disc and foraminal height showed significantly increase ($p < .001$, $p < .001$) after procedure. Pain and disability (ODI) significantly decreased due to PCD. An association was found between postoperative increase in SS and improvement in ODI ($r = 0.39$, $p < .05$). The change in low back pain was correlated with segmental scoliosis correction ($p < .001$). Moderate correlation was detected between the increase in disc height and ODI ($p < .05$) as well as leg pain ($p < .01$).

Conclusion PCD is an effective minimally invasive technique to treat axial pain and disability related to severe lumbar disc degeneration. Our study shows that an improvement in lumbar alignment and a significant indirect foraminal decompression could be achieved with the procedure. These changes can significantly contribute to the pain relief and increase in the patients' functional capacity.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.

Key points

1. PCD is a minimally invasive treatment option for elderly patients with several comorbidities to treat discogenic axial pain and disabilities.
2. PCD provides pain relief and restoration of quality of life.
3. Indirect foraminal decompression effect could be achieved via the restoration of disc height.
4. Lumbar alignment correction could be achieved with PCD.

parameter	pre	post	6m	post	6m
SS	32.848	33.564	33.564	33.564	33.564
PT	12.848	12.564	12.564	12.564	12.564
LL	45.848	45.564	45.564	45.564	45.564
TL	10.848	10.564	10.564	10.564	10.564
SL	15.848	15.564	15.564	15.564	15.564
LLC	18.848	18.564	18.564	18.564	18.564
LLS	20.848	20.564	20.564	20.564	20.564
LLD	22.848	22.564	22.564	22.564	22.564
LLH	24.848	24.564	24.564	24.564	24.564
LLW	26.848	26.564	26.564	26.564	26.564
LLT	28.848	28.564	28.564	28.564	28.564
LLB	30.848	30.564	30.564	30.564	30.564
LLA	32.848	32.564	32.564	32.564	32.564
LLG	34.848	34.564	34.564	34.564	34.564
LLF	36.848	36.564	36.564	36.564	36.564
LLE	38.848	38.564	38.564	38.564	38.564
LLD	40.848	40.564	40.564	40.564	40.564
LLC	42.848	42.564	42.564	42.564	42.564
LLB	44.848	44.564	44.564	44.564	44.564
LLA	46.848	46.564	46.564	46.564	46.564
LLG	48.848	48.564	48.564	48.564	48.564
LLF	50.848	50.564	50.564	50.564	50.564
LLE	52.848	52.564	52.564	52.564	52.564
LLD	54.848	54.564	54.564	54.564	54.564
LLC	56.848	56.564	56.564	56.564	56.564
LLB	58.848	58.564	58.564	58.564	58.564
LLA	60.848	60.564	60.564	60.564	60.564
LLG	62.848	62.564	62.564	62.564	62.564
LLF	64.848	64.564	64.564	64.564	64.564
LLE	66.848	66.564	66.564	66.564	66.564
LLD	68.848	68.564	68.564	68.564	68.564
LLC	70.848	70.564	70.564	70.564	70.564
LLB	72.848	72.564	72.564	72.564	72.564
LLA	74.848	74.564	74.564	74.564	74.564
LLG	76.848	76.564	76.564	76.564	76.564
LLF	78.848	78.564	78.564	78.564	78.564
LLE	80.848	80.564	80.564	80.564	80.564
LLD	82.848	82.564	82.564	82.564	82.564
LLC	84.848	84.564	84.564	84.564	84.564
LLB	86.848	86.564	86.564	86.564	86.564
LLA	88.848	88.564	88.564	88.564	88.564
LLG	90.848	90.564	90.564	90.564	90.564
LLF	92.848	92.564	92.564	92.564	92.564
LLE	94.848	94.564	94.564	94.564	94.564
LLD	96.848	96.564	96.564	96.564	96.564
LLC	98.848	98.564	98.564	98.564	98.564
LLB	100.848	100.564	100.564	100.564	100.564
LLA	102.848	102.564	102.564	102.564	102.564
LLG	104.848	104.564	104.564	104.564	104.564
LLF	106.848	106.564	106.564	106.564	106.564
LLE	108.848	108.564	108.564	108.564	108.564
LLD	110.848	110.564	110.564	110.564	110.564
LLC	112.848	112.564	112.564	112.564	112.564

Take Home Messages

1. PCD is a promising surgical method to treat discogenic axial pain and disability.
2. PCD suitable for advanced stage of disc degeneration in elderly patients with several comorbidities, when an open surgery is contraindicated.
3. PCD is contraindicated if A) there is no large vacuum phenomenon in the intradiscal space, B) general anesthesia is contraindicated.

Laszlo Kiss and Peter Pal Varga have equally contributed to the research.

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s00586-019-05966-7>) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

Keywords Percutaneous cement discoplasty · Radiological parameters · Outcome · Lumbar alignment · Indirect foraminal decompression

Introduction

Intervertebral discs undergo biomechanical and structural changes as a result of ageing and mechanical insults [1]. Intervertebral disc degeneration (IDD) can be characterized by the MRI-based Pfirrmann grading scale [2]. At the end stage (Pfirrmann Grade V), the disc space collapses and the nucleus pulposus disappears. In many discs, this process leads to the development of a vacuum sign visible on CT or X-ray [3, 4]. Parallel with the height reduction of the disc space, the dimensions of the neuroforamen continuously or dynamically decrease. From the biomechanical point of view, in standing or sitting position the foraminal stenosis deteriorates, but in lying position the dimensions of the foramen increase [4]. The cyclic repetitive compression of the nerve roots can lead to the development of chronic radiculopathy, and local and irradiating pain in case of axial loading [5]. Clinically patients' complaints are severe low back and leg pain, which was exacerbated in upright position and walking. In lying position, patients' pain relieves [6].

To address the clinical condition above in elderly patients, a minimally invasive surgical procedure, the percutaneous cement discoplasty (PCD) was introduced by Varga et al and later amended by Sola et al going in details with pearls and pitfalls of the technique [6, 7]. PCD procedure can be applied in case of vacuum discs where the intradiscal cavity can be filled with percutaneously injected PMMA. It provides a prompt segmental stabilizing effect and a supposed indirect decompression due to the increase in the foraminal dimensions [6]. Possible complications could be puncture-related bleeding, bone fracture, nerve root or spinal cord damage as well as PMMA extravasation into the paravertebral or epidural spaces. The procedure shows a possible influence on the sagittal and coronal alignment too. Clinical benefits of PCD had been already published, but its anatomical consequences have not been described yet.

Our objective was to evaluate the effects of PCD on the segmental and global lumbar anatomical parameters and their association with the clinical outcome on a prospective cohort.

Methods

Operative technique

Percutaneous cement discoplasty is performed in general anaesthesia, in prone position. On a radiolucent table, the intervertebral disc with the vacuum phenomenon is localized

by fluoroscopy. Stab incision is made 5–7 cm laterally from the median sagittal line. Jamshidi needle is introduced through Kambin's triangle to avoid nerve root injury. Under fluoroscopic control from lateral view, the needle is inserted into the disc space and a K-wire is inserted through the needle. After the removal of Jamshidi's tool, vertebroplasty working channel is inserted through the K-wire which is then removed. High-viscosity radiopaque PMMA cement is injected into the disc space. Continuous fluoroscopic control is mandatory to observe any adverse reaction like leakage while filling the disc space. The cement intake of the disc spaces varies in a wide range (3–10 ml). After the hardening of the cement, the work flow is removed [6]. General details of the procedure are represented in Table 1. During the procedure, no bleeding was observed but skin incision (1–2 ml).

Study population

All of the operative procedures were performed by a single surgeon (GJ). Preoperative, 1-day postoperative and 6-month follow-up imaging data and results of patient-reported outcome questionnaires (Oswestry Disability Index (ODI) and visual analogue scale (VAS)) for low back pain (LBP) and leg pain (LP) were collected and analysed. Sixty-three consecutive patients were operated with the technique in our tertiary care spine referral centre between 2014 and 2016. Patients with incomplete datasets ($n=4$), any other concomitant open surgeries (recalibration, nerve root decompression, fusion in adjacent spinal levels, $n=11$) or procedures done out segments L1-5 ($n=17$) were excluded from the study cohort. Surgical complications (cement leakage, $n=3$) are listed and classified according to

Table 1 Study population

<i>N</i>	28
Age (mean \pm SD)	75.4 \pm 7.4
Gender (M/F)	7/21
Extent of surgery (number of PCD levels)	
1 level	9 (9)
2 levels	6 (12)
3 levels	8 (24)
4 levels	5 (20)
Operating time (min, mean \pm SD)	
1 level	22.5 \pm 3.5
2 levels	25.0 \pm 5.0
3 levels	38.8 \pm 11.1
4 levels	64.3 \pm 12.7

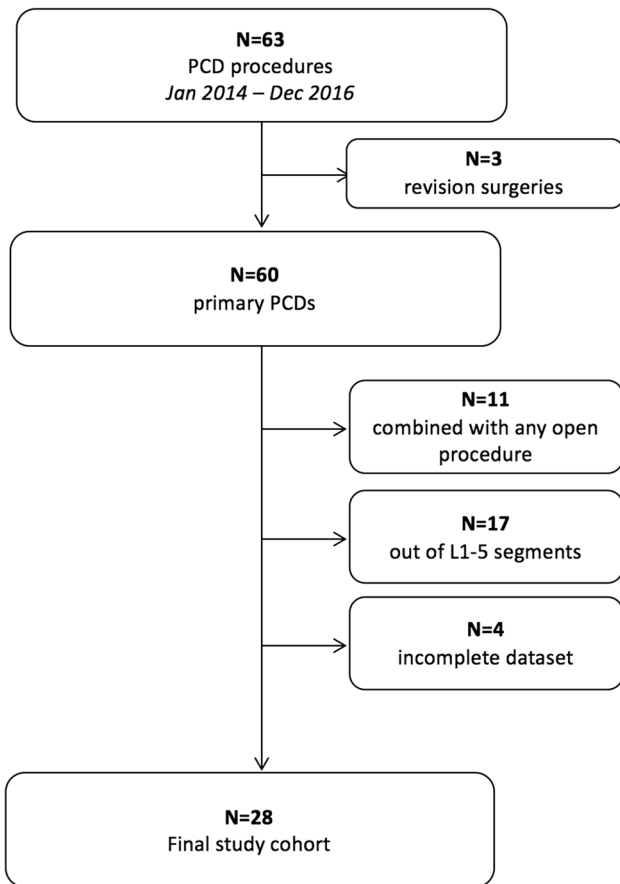


Fig. 1 Study population

Clavien–Dindo classification (supplementary Table 1); all cases were excluded from the final cohort (Fig. 1) [8]. The retrospective analysis of the prospectively collected data of 28 patients who underwent primary, single- or multilevel PCD in L1-5 segment was finally carried out (Table 1).

Radiological measurements

Lumbar standing antero-posterior and lateral X-rays were taken pre-, postoperatively and 6 months after the index surgery. From standing X-rays, pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), L1-5 lumbar lordosis (LL) and L1-5 lumbar scoliosis (LS) were measured (Figure 2a–c). Beyond the global parameters, the segmental parameters were measured to analyse the effect of PCD in the operated and in non-treated motion segments from L1 to L5. Segmental lordosis (sL) and segmental scoliosis (sS) were measured by the Cobb method. For the lordosis and scoliosis measurements, the adjacent endplates of the assessed segment were chosen to eliminate any possible bias coming from anatomical variations in vertebral bodies. Intervertebral disc height was considered as the distance between the adjacent endplates at anterior (DHA) and posterior (DHP) borders of the vertebral bodies. Interpedicular height (IPH) defined by the distance between the centres of the adjacent pedicles was measured to follow the change in the height of the foramen. Mean IPH of each level from L1 to L5 was analysed. Measurements were taken using the eRad PACS viewer version 7.2 (eRAD Inc., Greenville US). All the radiological measurements were taken by the first author [6].

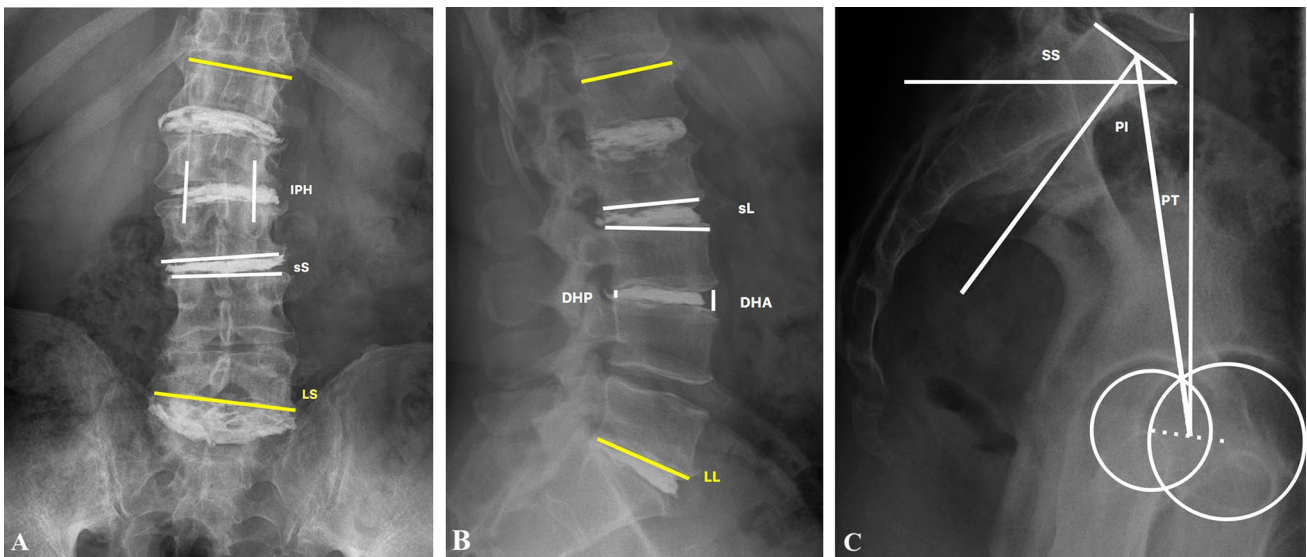


Fig. 2 Spinopelvic parameters in standard standing X-ray. **a** Antero-posterior view: LS (lumbar scoliosis), sS (segmental scoliosis), IPH (interpedicular height). **b** Lateral view: LL (lumbar lordosis), sL (seg-

mental lordosis), DHA (disc height anterior), DHP (disc height posterior). **c** Pelvic parameters in lateral view: SS (sacral slope), PI (pelvic incidence), PT (pelvic tilt)

Statistical analysis

All parameters were measured twice with a 2-month interval by the same rater on a subset of 20 samples, and interclass correlation coefficient (ICC) was calculated to evaluate the reliability of the measurement methods. Distribution of data was checked by Shapiro–Wilk test. In case of the spinopelvic radiological parameters, one-way repeated measures ANOVA and nonparametric Friedman test were conducted to determine the statistically significant differences over the course of a 6-month follow-up period. Pearson's (r) and Spearman (ρ) correlation tests were run to assess the relationship between the change in spinopelvic parameters and the clinical outcome. Cohen's standard was used to evaluate the strength of the relationship (r/ρ between 0.1 and 0.29 represents a 'small', r/ρ between 0.3 and 0.49 represents a 'medium' and r/ρ above 0.5 represents a 'large' association). Statistical analyses were performed using SPSS 20.0 software (IBM SPSS statistics software, Chicago, IL, USA). A p -value less than 0.05 was considered significant.

Results

One hundred twelve segments (65 PCD and 47 without PCD) were analysed in 28 patients (Table 1). The sample size provided a more than 90% power of the study to determine a 2.9 ± 2.6 -point difference in VAS as well as a 4.2 ± 5.3 -degree change in segmental scoliosis. Reliability of the radiological measurements was proved to be excellent based on the calculated ICC (Supplementary Table 2) [9]. The results are reported comparing the preoperative (pre-op), postoperative (post-op) and 6-month follow-up (6 M FU) data (Table 2). There were no postoperative complications in the study cohort.

Pelvic parameters

The pelvic incidence was constant during the study period (pre-op vs. post-op $p > .05$ and post-op vs. 6 M FU $p > .05$). Sacral slope significantly increased after the intervention and the change remained constant (pre-op vs. post-op $p < .01$, post-op vs. 6 M FU $p > .05$). A significant, constant decrease in pelvic tilt was observed after the PCD procedure (pre-op vs. post-op $p < .05$, post-op vs. 6 M FU $p > .05$).

Spinal parameters

There was not any significant change in the global L1-5 lumbar lordosis after the procedure; however, a 3.4° trend to significant increase in the lordosis was observed ($p > .05$). Segmental lordosis significantly increased in both segments with and without PCD ($p < .05$ and $p < .05$), and the

change was constant during the follow-up period. In case of all measured segments, the segmental lordosis ($4.4^\circ \pm 3.8^\circ$ vs. $6.6^\circ \pm 4.8^\circ$ vs. $6.9^\circ \pm 4.7^\circ$) showed significant, constant change after the procedure ($p < .05$). Correction of lumbar scoliosis could be achieved and maintained ($7.4^\circ \pm 6.4^\circ$ vs. $5.6^\circ \pm 5.4^\circ$ vs. $5.7^\circ \pm 6.1^\circ$). The degree of scoliosis was statistically different pre- and postoperatively ($p < .05$), but there was no significant change after 6 months ($p > .05$). A significant segmental deformity correction was observed after the PCD procedure without any change over the 6-month follow-up ($4.7^\circ \pm 3.7^\circ$ vs. $2.4^\circ \pm 1.9^\circ$ vs. $2.5^\circ \pm 2.1^\circ$, $p < .05$ and $p > .05$). In case of multilevel PCDs (2 or more segments), the change in lumbar scoliosis ($-2.2^\circ \pm 3.2^\circ$) and segmental scoliosis ($2.5^\circ \pm 4.5^\circ$) showed significant difference compared to single-level PCDs (change in LS = $-0.7^\circ \pm 2.4^\circ$ and in sS = $7.3^\circ \pm 5.4^\circ$; $p < .05$ and $p < .01$ compared to multilevel PCD, respectively). The change in posterior disc height (0.2 ± 2.9 mm vs. 2.1 ± 2.9 mm, $p < .05$) showed more increase in multilevel PCDs. The improvement in leg pain (-1.8 ± 2.5 vs. -3.2 ± 2.3 , $p < .05$) was significantly greater in multilevel procedures. The impact of PCD based on the number of discoplasties is presented in Supplementary Table 3.

Intervertebral space parameters

In sagittal plane, the anterior (DHA) and posterior disc height (DHP) showed a significant increase after the surgery (DHA: 5.5 ± 2.7 mm vs. 9.1 ± 2.8 mm, $p < .001$; DHP: 4.0 ± 2.3 mm vs. 5.5 ± 2.6 mm, $p < .001$). In both parameters, the change was significantly higher in PCD-treated segments (DHA mean change: 4.7 ± 3.0 mm vs. 2.1 ± 3.3 mm, $p < .001$, and DHP mean change: 2.8 ± 3.4 mm vs. 0.0 ± 2.4 mm, $p < .001$, in case of segments with and without PCD, respectively). IPH was significantly increased in segments with PCD, and the change was constant (28.8 ± 3.6 mm vs. 32.8 ± 4.5 mm vs. 31.7 ± 4.6 mm, $p < .001$).

Clinical outcome

ODI and VAS (both LP and LBP) significantly decreased 6 months after the PCD procedure (Table 2). There was a medium association between the increase in sacral slope and improvement in ODI postoperatively ($r = -0.39$, $p < .05$) (Fig. 3). We also found that the change in LBP significantly correlated with the degree of segmental scoliosis correction ($\rho = 0.32$, $p < .001$). There was also a weak correlation between the increase in DHA and ODI ($\rho = -0.189$, $p < .05$) and between DHA and DHP and LP ($\rho = -0.202$, $p < .05$ and $\rho = -0.274$, $p < .05$, respectively).

Table 2 Results of radiological measurements

	Pre-op (mean ± SD)	Post-op (mean ± SD)	6 M FU (mean ± SD)	Post-op vs Pre-op (mean change, %)	<i>p</i>	6 M FU vs post-op (mean change, %)	<i>p</i>
<i>Pelvic parameters</i>							
PI (°) [#]	54.5 ± 8.9	54.7 ± 9.5	55.2 ± 9.6	0.2 (0.3%)	> .05	0.5 (0.9%)	> .05
SS (°) [#]	33.6 ± 7.1	36.5 ± 7.0	35.0 ± 6.8	2.9 (8.6%)	< .01	− 1.5 (− 4.11%)	> .05
PT (°) [#]	21.1 ± 10.1	18.3 ± 8.1	19.9 ± 9.1	− 2.8 (− 13.28%)	< .05	1.6 (8.7%)	> .05
<i>Spinal parameters</i>							
LL (°) [#]	35.5 ± 16.3	38.9 ± 16.5	38.0 ± 16.7	3.4 (9.5%)	> .05	− 0.9 (− 2.32%)	> .05
sL (°)	4.4 ± 3.8	6.6 ± 4.8	6.9 ± 4.7	2.2 (73.6%)	< .05	0.3 (4.5%)	> .05
Segments with PCD (°)	3.2 ± 3.4	4.7 ± 3.7	5.4 ± 3.7	1.5 (38.2%)	< .05	0.7 (14.89%)	> .05
Segments w/o PCD (°)	5.9 ± 3.8	9.0 ± 4.8	9.1 ± 4.9	3.1 (136.8%)	< .05	0.1 (1.1%)	> .05
LS (°)	7.4 ± 6.4	5.6 ± 5.4	5.7 ± 6.1	− 1.8 (− 12.5%)	< .05	0.1 (1.1%)	> .05
sS (°)	6.5 ± 4.8	2.3 ± 2.1	2.6 ± 2.2	− 4.2 (− 52.1%)	< .001	0.3 (13%)	> .05
Segments with PCD (°)	4.7 ± 3.7	2.4 ± 1.9	2.5 ± 2.1	− 2.3 (− 33.14%)	< .05	0.1 (4.1%)	> .05
Segments w/o PCD (°)	8.8 ± 5.0	2.2 ± 2.3	2.6 ± 2.3	− 6.6 (− 66%)	< .001	0.4 (18.18%)	> .05
<i>Intervertebral parameters</i>							
DHA (mm)	5.5 ± 2.7	9.1 ± 3.2	8.3 ± 3.3	3.6 (65.4%)	< .001	− 0.8 (− 8.8%)	< .001
Segments with PCD (mm)	4.5 ± 2.1	9.2 ± 2.8	8.4 ± 2.9	4.7 (104.4%)	< .001	− 0.8 (− 8.7%)	< .05
Segments w/o PCD (mm)	6.8 ± 2.8	8.9 ± 3.6	8.2 ± 3.8	2.1 (30.8%)	< .001	− 0.7 (− 7.8%)	< .05
DHP (mm)	4.0 ± 2.2	5.5 ± 2.7	5.2 ± 2.7	1.5 (37.5%)	< .001	− 0.3 (− 5.4%)	< .05
Segments with PCD (mm)	4.0 ± 2.3	6.8 ± 2.6	6.5 ± 2.5	2.8 (70%)	< .001	− 0.3 (− 4.4%)	> .05
Segments w/o PCD (mm)	4.0 ± 2.0	4.0 ± 2.0	3.4 ± 1.6	0.0 (0%)	> .05	− 0.6 (− 15%)	< .05
IPH (mm)	30.1 ± 3.7	32.4 ± 3.3	31.5 ± 3.4	2.3 (7.6%)	< .05	− 0.9 (− 2.8%)	< .001
Segments with PCD (mm)	28.8 ± 3.6	32.8 ± 4.8	31.7 ± 4.6	4.0 (13.8%)	< .001	− 1.1 (− 3.3%)	< .05
Segments w/o PCD (mm)	31.4 ± 4.0	16.0 ± 3.3	31.1 ± 3.5	− 15.4 (− 49.1%)	> .05	15.1 (94.3%)	> .05
<i>Clinical outcome</i>							
ODI	55.4 ± 13.9	–	37.9 ± 21.4	–	–	− 37.9 (− 31.5%)	< .001
LBP	5.9 ± 3.0	–	3.5 ± 2.5	–	–	− 3.5 (− 40.6%)	< .001
LP	6.9 ± 2.4	–	4.0 ± 2.7	–	–	− 4.0 (− 42%)	< .001

PI (pelvic incidence, SS (sacral slope), PT (pelvic tilt), LL (lumbar lordosis), LS (lumbar scoliosis), sL (segmental lordosis), sS (segmental scoliosis), DHA (disc height anterior), DHP (disc height posterior), IPH (interpedicular height), ODI (Oswestry Disability Index), LBP (low back pain), LP (leg pain). Pre-op vs. post-op and post-op vs. FU change percentage represented in parentheses

Normally distributed data

Discussion

In the present study, the effect of a minimally invasive surgical procedure (PCD) on lumbar segmental and global radiological parameters and clinical outcome was investigated. Disability and pain significantly improved due to the PCD procedure, and the clinical improvement at 6-month follow-up (17.5 points in ODI, 2.4 points in LBP, and 2.9

points in LP) was more than the consensual cut-off values for minimal important change in ODI and VAS [10]. Nevertheless, the pain relief and the functional improvement are multidimensional consequences; this clinical benefit can be related to the impact of the PCD procedure on the morphological parameters of the lumbar spine. The improvement in patients' disability can be related to the improvement in the sagittal spinopelvic alignment. We found a positive correlation between the increased sacral slope due to the surgery

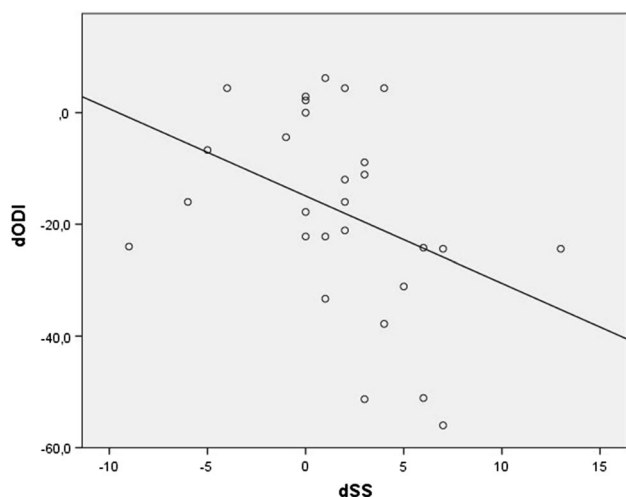


Fig. 3 Association between the postoperative change in sacral slope (SS) and Oswestry Disability Index (ODI) ($r = -0.39$, $p < .05$)

and the postoperative functional capacity (i.e. decreased ODI). This association was previously demonstrated in adult deformity patients after correction surgery [11–14], and the strength of the correlation what we found is similar to the results of others [11, 13]. Pain weakly but significantly correlated with the change in some segmental parameters such as the correction of the segmental scoliosis and the disc height. Beyond the segmental stabilization effect of the procedure, both associations can be explained by the change in the foraminal area [15] and the consequent indirect decompression effect [15–17] of PCD what was clearly showed by the radiological parameters.

In treated segments (i.e. in pain generator vacuum discs), the preoperative anterior disc height was significantly reduced compared to the untreated discs (4.5 ± 2.1 mm vs. 6.8 ± 2.8 mm, $p < .001$), while the mean posterior disc height was not different in these two subgroups. A decreased IPH (28.8 ± 3.6 mm vs. 31.4 ± 4.0 mm, $p < .001$) and segmental lordosis ($3.2^\circ \pm 3.4^\circ$ vs. $5.9^\circ \pm 3.8^\circ$, $p < .001$) were also measured in the severely degenerated disc candidate for PCD. These results show the effect of the advanced disc degeneration on the morphology of the motion segment. In this context, the favourable effect of the MIS procedure on these parameters is more straightforward. Due to the PCD, not only the improvement in the above-mentioned parameters but also a significant increase in the posterior disc height (DHP) was noticed. The segmental indirect decompression effect of the procedure—characterized by the increased IPH and DHP—was also associated with the correction of the segmental sagittal and coronal alignment. A significant improvement in the global coronal alignment and in segmental lordosis and scoliosis was observed even in the untreated segments. This latter association can be explained

by the pain relief and the consequent reduction in the antalgia what can be also significantly related to the observed improvement in the functional capacity of the patients [18]. Multilevel PCDs had a higher impact on the decrease in lumbar scoliosis.

Our paper highlights the positive influence of PCD on global and segmental spinopelvic radiological parameters and their association with the clinical outcome. However, the study has got some limitations. Dataset of 63 consecutive patients operated between 2014 and 2016 were analysed, but patients having other concomitant open surgeries ($n = 11$, 17.5%), incomplete follow-up data ($n = 4$, 6.3%), having a surgical complication (cement leakage) ($n = 3$, 4.7%) or procedures done out of segments L1–5 ($n = 17$, 26.2%) were excluded from the final study cohort. Although the final study cohort provided a good power of the study, the excluded subjects could modify the results. The number of the patients with prospective dataset was not too high, but the analyses of all their L1–5 segments provided a good power of the study. Full standing X-ray was available only for a subset of patients, so the influence of PCD on the global alignment is not known. The pain relief effect of the segmental stabilization (ie. ROM reduction) alone is not known; thus, the clinical result of the different dimensions of the procedure (stabilization, indirect decompression, alignment correction) has not been elucidated so far. To validate our results and to clarify the above-mentioned biomechanical and clinical issues, further biomechanical studies and multicentre clinical trials with long-term follow-up are needed.

Conclusions

Elderly patients with several comorbidities suffering from severe disc degeneration are often not suitable for extended open surgeries because of the increased perioperative risk of complications. The main purpose of the minimally invasive PCD surgery is pain relief and restoration of quality of life. Our results show that PCD can not only have a segmental stabilizing effect, but also provide a foraminal decompression and lumbar alignment correction effect.

Funding Aron Lazary has received research grants from the Hungarian Scientific Research Fund, Budapest, Hungary, Award number: OTKA FK123884.

Compliance with ethical standards





Conflict of interest The authors declare that they have no conflict of interest.

References

- Shah AMKSYJ, Chan WCW, Chan D (2017) Intervertebral disc degeneration. Springer, Cham
- Pfirschmann CW, Metzendorf A, Zanetti M, Hodler J, Boos N (2001) Magnetic resonance classification of lumbar intervertebral disc degeneration. *Spine* 26:1873–1878
- Adams MA, Dolan P (2012) Intervertebral disc degeneration: evidence for two distinct phenotypes. *J Anat* 221:497–506. <https://doi.org/10.1111/j.1469-7580.2012.01551.x>
- Leone A, Guglielmi G, Cassar-Pullicino VN, Bonomo L (2007) Lumbar intervertebral instability: a review. *Radiology* 245:62–77. <https://doi.org/10.1148/radiol.2451051359>
- Dolan P, Luo J, Pollintine P, Landham PR, Stefanakis M, Adams MA (2013) Intervertebral disc decompression following endplate damage: implications for disc degeneration depend on spinal level and age. *Spine* 38:1473–1481. <https://doi.org/10.1097/BRS.0b013e318290f3cc>
- Varga PP, Jakab G, Bors IB, Lazary A, Szoverfi Z (2015) Experiences with PMMA cement as a stand-alone intervertebral spacer: percutaneous cement discoplasty in the case of vacuum phenomenon within lumbar intervertebral discs. *Der Orthopade* 44(Suppl 1):S1–S7. <https://doi.org/10.1007/s00132-014-3060-1>
- Sola C, Camino Willhuber G, Kido G, Pereira Duarte M, Bendersky M, Mereles M, Petracchi M, Gruenberg M (2018) Percutaneous cement discoplasty for the treatment of advanced degenerative disk disease in elderly patients. *Eur Spine J*. <https://doi.org/10.1007/s00586-018-5547-7>
- Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 240(2):205–213
- Cicchetti DV (1994) Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychol Assess* 6:284–290. <https://doi.org/10.1037/1040-3590.6.4.284>
- Ostelo RW, Deyo RA, Stratford P, Waddell G, Croft P, Von Korf M, Bouter LM, de Vet HC (2008) Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. *Spine* 33:90–94. <https://doi.org/10.1097/BRS.0b013e31815e3a10>
- Beyer F, Geier F, Bredow J, Oppermann J, Eysel P, Sobottke R (2015) Influence of spinopelvic parameters on non-operative treatment of lumbar spinal stenosis. *Technol Health Care* 23:871–879. <https://doi.org/10.3233/THC-151032>
- Chapman TM Jr, Baldus CR, Lurie JD, Glassman SD, Schwab FJ, Shaffrey CI, Lafage V, Boachie-Adjei O, Kim HJ, Smith JS, Crawford CH 3rd, Lenke LG, Buchowski JM, Edwards C 2nd, Koski T, Parent S, Lewis S, Kang DG, McClendon J Jr, Metz L, Zebala LP, Kelly MP, Spratt KF, Bridwell KH (2016) Baseline patient-reported outcomes correlate weakly with radiographic parameters: a multicenter, prospective NIH adult symptomatic lumbar scoliosis study of 286 patients. *Spine* 41:1701–1708. <https://doi.org/10.1097/BRS.0000000000001613>
- Eskilsson K, Sharma D, Johansson C, Hedlund R (2017) The impact of spinopelvic morphology on the short-term outcome of pedicle subtraction osteotomy in 104 patients. *J Neurosurg Spine* 27:74–80. <https://doi.org/10.3171/2016.11.SPINE16601>
- Simon J, Longis PM, Passuti N (2017) Correlation between radiographic parameters and functional scores in degenerative lumbar and thoracolumbar scoliosis. *Orthop Traumatol Surg Res* 103:285–290. <https://doi.org/10.1016/j.otsr.2016.10.021>
- Castellvi AE, Nienke TW, Marulanda GA, Murtagh RD, Santoni BG (2014) Indirect decompression of lumbar stenosis with transposas interbody cages and percutaneous posterior instrumentation. *Clin Orthop Relat Res* 472:1784–1791. <https://doi.org/10.1007/s11999-014-3464-6>
- Mallham GM, Parker RM, Goss B, Blecher CM (2015) Clinical results and limitations of indirect decompression in spinal stenosis with laterally implanted interbody cages: results from a prospective cohort study. *European Spine J* 24(Suppl 3):339–345. <https://doi.org/10.1007/s00586-015-3807-3>
- Pereira EA, Farwana M, Lam KS (2017) Extreme lateral interbody fusion relieves symptoms of spinal stenosis and low-grade spondylolisthesis by indirect decompression in complex patients. *J Clin Neurosci* 35:56–61. <https://doi.org/10.1016/j.jocn.2016.09.010>
- Endo K, Suzuki H, Tanaka H, Kang Y, Yamamoto K (2010) Sagittal spinal alignment in patients with lumbar disc herniation. *European Spine J* 19:435–438. <https://doi.org/10.1007/s00586-009-1240-1>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Affiliations

Laszlo Kiss^{1,2,3}  · Peter Pal Varga¹  · Zsolt Szoverfi^{1,4}  · Gabor Jakab¹  · Peter Endre Eltes^{1,2,3}  · Aron Lazary^{1,4} 

✉ Aron Lazary
aron.lazary@bhc.hu

¹ National Center for Spinal Disorders, Buda Health Center, Királyhágó St. 1-3, Budapest 1126, Hungary

² In Silico Biomechanics Laboratory, National Center for Spinal Disorders, Buda Health Center, Budapest, Hungary

³ School of PhD Studies, Semmelweis University, Budapest, Hungary

⁴ Department of Musculoskeletal Oncology, Semmelweis University, Budapest, Hungary