

The Effect of Rod Distraction with Pedicle Screws on Lumbar Canal and Foraminal Diameter in Lumbar Surgery in Nigeria

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Received: 20 Aug 2026; Accepted: 24 Sep 2026; Published: 30 Sep 2026

Citation: Kawu Ahidjo Abdulkadiri, Abubakar Kabir, Nurudeen Aminu Muhammad, et al. The Effect of Rod Distraction with Pedicle Screws on Lumbar Canal and Foraminal Diameter in Lumbar Surgery in Nigeria. J Med - Clin Res & Rev. 2026; 10(9): 1-5.

ABSTRACT

Background: Lumbar canal and foraminal stenosis are common degenerative conditions causing neurogenic claudication and radiculopathy. Indirect decompression via pedicle screw distraction, utilizing ligamentotaxis, has emerged as an alternative to direct decompression. However, the quantitative relationship between the magnitude of rod distraction and the resulting canal and foraminal opening has not been defined in Nigerian patients.

Methods: A retrospective cohort study of 63 patients who underwent pedicle screw insertion and rod distraction alone for lumbar canal and foraminal stenosis at the National Orthopaedic Hospital Dala, Kano, from January 2021 to June 2025 was conducted. Preoperative and postoperative MRI was used to measure the anteroposterior canal diameter and foraminal diameter from L2 to L5. Intraoperative pedicle distance at insertion and after distraction was recorded. Correlation and linear regression analyses were performed to determine the relationship between distraction magnitude and canal/foraminal opening.

Results: The mean distraction achieved was 3.2 ± 1.1 mm per level. The mean increase in anteroposterior canal diameter was 2.4 ± 0.8 mm (range 1.2–4.2 mm). The mean increase in foraminal diameter was 2.1 ± 0.7 mm (range 1.0–3.8 mm). There was a strong positive correlation between rod distraction and canal opening ($r=0.84$, $p<0.001$) and between rod distraction and foraminal opening ($r=0.81$, $p<0.001$). The derived predictive equations were: Canal opening (mm) = $0.68 + 0.54 \times \text{Distraction (mm)}$ and Foraminal opening (mm) = $0.52 + 0.50 \times \text{Distraction (mm)}$.

Conclusions: Rod distraction produces predictable, measurable increases in lumbar canal and foraminal dimensions. The derived equations provide a practical tool for estimating the expected decompression effect and guiding the magnitude of distraction during surgery.

Keywords

Lumbar canal stenosis, Foraminal stenosis, Pedicle screw distraction, Ligamentotaxis, Indirect decompression, Nigeria.

Introduction

Lumbar spinal stenosis is a degenerative condition characterised

by narrowing of the central spinal canal and/or the intervertebral foramina, leading to compression of neural elements and a constellation of symptoms including neurogenic claudication, radicular pain, and functional disability [1,2]. It is the most common indication for spinal surgery in adults over 65 years of age, and its prevalence is increasing as the population ages [3,4].

In Nigeria, lumbar canal stenosis is a frequent indication for surgical intervention, with degenerative changes, disc prolapse, and thickened ligamentum flavum being the predominant causes [5,6].

The goals of surgical treatment are decompression of neural elements, restoration of canal and foraminal dimensions, and stabilisation of the affected segments [7,8]. Traditional surgical approaches involve direct decompression via laminectomy, foraminotomy, and excision of the ligamentum flavum [9,10]. However, direct decompression can destabilize the spine, necessitating fusion, and may be associated with complications such as dural tears, nerve root injury, and postoperative instability [11,12].

Indirect decompression using pedicle screw distraction, also known as ligamentotaxis, has emerged as an alternative or adjunct to direct decompression [13,14]. The principle of ligamentotaxis relies on the intact posterior longitudinal ligament (PLL) and the annulus fibrosus to reduce retropulsed disc fragments and restore canal dimensions when distraction is applied across the affected segment [15,16]. A biomechanical study demonstrated that ligamentotaxis can effectively reduce canal compromise in burst fractures, with a mean canal clearance of 20% after distraction [17]. A systematic review of indirect decompression in lumbar spine surgery found that the technique was associated with significant improvements in patient-reported outcomes [18]. Clinical studies have reported significant increases in canal and foraminal dimensions following pedicle screw distraction, although the magnitude of effect varies widely depending on the degree of distraction and the integrity of the posterior ligamentous complex [19,20].

Despite the recognition of ligamentotaxis as a mechanism of indirect decompression, the quantitative relationship between the magnitude of rod distraction and the resulting canal and foraminal opening has not been defined. This gap in knowledge limits the surgeon's ability to predict the decompressive effect of a given distraction force and to tailor the magnitude of distraction to the individual patient's pathology.

This study aimed to: (1) measure the change in lumbar canal and foraminal diameter following pedicle screw distraction in Nigerian patients; (2) correlate the magnitude of rod distraction with the change in canal and foraminal dimensions; and (3) derive a predictive equation for estimating the expected decompression effect per millimeter of distraction.

Methodology

Study Design and Setting

This was a retrospective cohort study conducted at the National Orthopaedic Hospital Dala, Kano, Nigeria -a 250-bed tertiary orthopaedic referral centre serving northern Nigeria. The study covered the period from 1 January 2021 to 30 June 2025. Ethical approval was obtained from the institutional research ethics committee and individual patient consent was waived due to the retrospective nature.

Participants

All consecutive patients who underwent surgery for lumbar canal stenosis and foraminal stenosis during the study period were eligible. Inclusion criteria: (1) clinical and radiological diagnosis of lumbar canal and/or foraminal stenosis; (2) surgical treatment with pedicle screw insertion and rod distraction alone (without direct decompression); (3) availability of preoperative and postoperative MRI; (4) complete medical and radiological records. Exclusion: patients with previous lumbar surgery, trauma, tumour, infection, or incomplete records.

A total of 63 patients met the inclusion criteria.

Surgical Technique

All patients underwent posterior pedicle screw fixation with rod distraction under general anaesthesia. The procedure involved:

- Standard posterior midline approach with subperiosteal dissection
- Pedicle screw insertion at the affected levels (L2–L5) using freehand technique with C-arm confirmation
- Placement of contoured rods
- Application of distraction across the affected segment(s) using a rod distractor
- Measurement of pedicle distance before and after distraction using a calibrated ruler
- Final tightening of the set screws and layered closure

No direct decompression (laminectomy or foraminotomy) was performed. Ligamentotaxis was the sole mechanism of decompression.

Radiological Assessment

Preoperative and postoperative MRI (within 3 months of surgery) was used to measure:

- Anteroposterior canal diameter (mm): Measured at the mid-sagittal plane at each operated level (L2–L5).
- Foraminal diameter (mm): Measured at the narrowest point of the intervertebral foramen on parasagittal and axial images.
- Measurements were performed independently by two consultant radiologists blinded to clinical outcomes, with disagreements resolved by consensus. The intraclass correlation coefficient (ICC) for inter-observer reliability was 0.91 for canal diameter and 0.88 for foraminal diameter.

Measurement of Distraction

Intraoperative pedicle distance was measured using a calibrated ruler before and after distraction at each operated level. The change in pedicle distance (mm) was recorded as the magnitude of distraction.

Statistical Analysis

Data were analysed using SPSS version 26. Continuous variables are presented as mean±SD, categorical as frequencies (%). Paired t-tests compared preoperative and postoperative canal and foraminal diameters. Pearson correlation assessed the relationship between distraction magnitude and canal/foraminal opening. Linear regression was used to derive predictive equations.

Statistical significance was set at $p<0.05$.

Results

Patient Characteristics

A total of 63 patients were included. The mean age was 56.4 ± 12.8 years; 38 (60.3%) were male. The most common operated level was L4-L5 (46.0%), followed by L3-L4 (28.6%) and L5-S1 (15.9%). Table 1 presents the baseline characteristics.

Table 1: Baseline Characteristics of 63 Patients.

Characteristic	Category	n (%)
Age (years)	Mean $\pm$ SD	56.4 ± 12.8
	Male	38 (60.3)
Sex	Female	25 (39.7)
Operated level	L2-L3	6 (9.5)
	L3-L4	18 (28.6)
	L4-L5	29 (46.0)
	L5-S1	10 (15.9)
Number of levels	Single-level	42 (66.7)
	Two-level	21 (33.3)

Distraction Achieved

The mean distraction achieved was 3.2 ± 1.1 mm per level (range 1.5–5.8 mm). Distraction was greater at L4-L5 (3.6 ± 1.2 mm) compared with L2-L3 (2.8 ± 0.9 mm) and L3-L4 (3.0 ± 1.0 mm), reflecting the greater mobility of the lower lumbar segments. Table 2 presents the distraction by level.

Table 2: Distraction Achieved by Operated Level.

Level	Mean Distraction (mm)	Range (mm)
L2-L3	2.8 ± 0.9	1.5 – 4.2
L3-L4	3.0 ± 1.0	1.8 – 5.0
L4-L5	3.6 ± 1.2	2.0 – 5.8
L5-S1	3.4 ± 1.1	2.0 – 5.5
Overall	3.2 ± 1.1	1.5 – 5.8

Canal and Foraminal Diameter Changes

Table 3 presents the preoperative and postoperative canal and foraminal diameters. The mean anteroposterior canal diameter increased from 8.4 ± 1.6 mm to 10.8 ± 1.8 mm (mean increase 2.4 ± 0.8 mm, $p<0.001$). The mean foraminal diameter increased from 4.2 ± 1.1 mm to 6.3 ± 1.3 mm (mean increase 2.1 ± 0.7 mm, $p<0.001$).

Table 3: Canal and Foraminal Diameter Changes.

Parameter	Preoperative (mm)	Postoperative (mm)	Mean Change (mm)	p-value
Canal diameter (AP)	8.4 ± 1.6	10.8 ± 1.8	2.4 ± 0.8	<0.001
Foraminal diameter	4.2 ± 1.1	6.3 ± 1.3	2.1 ± 0.7	<0.001

Correlation between Distraction and Decompression

There was a strong positive correlation between the magnitude of rod distraction and the increase in canal diameter ($r=0.84$, $p<0.001$)

and between distraction and increase in foraminal diameter ($r=0.81$, $p<0.001$). Table 4 presents the correlation matrix.

Table 4: Correlation between Distraction and Canal/Foraminal Opening.

Parameter	Canal Opening (r)	Foraminal Opening (r)	p-value
Distraction (mm)	0.84	0.81	<0.001
Canal opening (mm)	–	0.76	<0.001

Predictive Equations

Linear regression analysis yielded the following predictive equations:

$$\text{Canal opening (mm)} = 0.68 + 0.54 \times \text{Distraction (mm)}$$

$$\text{Foraminal opening (mm)} = 0.52 + 0.50 \times \text{Distraction (mm)}$$

The model for canal opening explained 71% of the variance ($R^2=0.71$, $p<0.001$), and the model for foraminal opening explained 66% of the variance ($R^2=0.66$, $p<0.001$). Table 5 presents example predictions for different magnitudes of distraction.

Table 5: Predicted Canal and Foraminal Opening by Distraction Magnitude.

Distraction (mm)	Predicted Canal Opening (mm)	Predicted Foraminal Opening (mm)
1.0	1.22	1.02
2.0	1.76	1.52
3.0	2.30	2.02
4.0	2.84	2.52
5.0	3.38	3.02

Discussion

This study provides the first quantitative analysis of the relationship between pedicle screw distraction and canal/foraminal opening in Nigerian patients with lumbar stenosis. The findings demonstrate that rod distraction produces predictable, measurable increases in lumbar canal and foraminal dimensions, with strong correlations between the magnitude of distraction and the resulting decompression.

The mean distraction of 3.2 ± 1.1 mm per level in our cohort is comparable to the 2–4 mm reported in other studies of indirect decompression [13,14]. Distraction was greatest at L4-L5 (3.6 ± 1.2 mm), reflecting the greater segmental mobility of the lower lumbar spine compared with the upper lumbar levels. A biomechanical study found that the L4-L5 segment has the greatest range of motion in the lumbar spine, which may allow greater distraction without excessive force [16]. The mean distraction achieved in our study is consistent with the recommendation that distraction should be limited to 2–4 mm to avoid over-distraction and iatrogenic injury [15].

The mean increase in canal diameter of 2.4 ± 0.8 mm (28.6% increase from baseline) is consistent with the literature on ligamentotaxis. A study on indirect decompression in lumbar burst fractures reported a mean canal clearance of 20% after distraction [17]. A systematic review of indirect decompression found that the technique was

associated with significant improvements in canal dimensions, with a mean increase of 1.5–3.0 mm [18]. The mean increase in foraminal diameter of 2.1 ± 0.7 mm (50.0% increase from baseline) is particularly notable, as foraminal stenosis is a common cause of radiculopathy that is often inadequately addressed by central decompression alone [19].

The strong positive correlations between distraction and canal opening ($r=0.84$) and foraminal opening ($r=0.81$) confirm that the magnitude of distraction is a reliable predictor of the decompressive effect. This is consistent with the biomechanical principle of ligamentotaxis, where distraction tightens the PLL and annulus fibrosus, reducing retropulsed disc material and restoring canal dimensions [15,16]. The correlation coefficients in our study are higher than those reported in some studies, possibly because our cohort included only patients with intact posterior ligamentous complexes, which are essential for ligamentotaxis to be effective [17].

The derived equations-Canal opening (mm) = $0.68 + 0.54 \times \text{Distraction (mm)}$ and Foraminal opening (mm) = $0.52 + 0.50 \times \text{Distraction (mm)}$ -provide a practical tool for estimating the expected decompression effect per millimeter of distraction. For example, a 3-mm distraction would be predicted to produce a 2.30-mm increase in canal diameter and a 2.02-mm increase in foraminal diameter. This information can guide the surgeon in determining the optimal magnitude of distraction, particularly when the preoperative canal and foraminal dimensions are known from MRI.

The finding that the canal opening per millimetre of distraction (0.54 mm) is slightly greater than the foraminal opening per millimetre (0.50 mm) reflects the greater compliance of the central canal compared with the foramen, which is bounded by bony structures and the ligamentum flavum [20].

A study on indirect decompression in lumbar spine surgery found that the mean increase in canal diameter was 2.1 mm (range 1.2–3.5 mm) and the mean increase in foraminal diameter was 1.8 mm (range 0.8–3.2 mm) [18]. Our findings of 2.4 mm and 2.1 mm, respectively, are slightly higher, which may reflect the use of a more aggressive distraction protocol or differences in patient selection. A biomechanical study on ligamentotaxis in burst fractures reported that distraction of 5 mm produced a 3.5-mm increase in canal diameter, which is consistent with our equation predicting a 3.38-mm increase at 5 mm distraction [17].

The findings of this study have several implications for clinical practice:

1. Preoperative planning: The predictive equations can be used to estimate the magnitude of distraction required to achieve a target canal or foraminal opening based on preoperative MRI measurements.
2. Intraoperative decision-making: The surgeon can use the equations to determine how much distraction is needed to achieve adequate decompression, potentially avoiding the

need for direct decompression in selected patients.

3. Patient selection: Indirect decompression is most effective in patients with intact posterior ligamentous complexes and mobile segments. Patients with rigid deformities or deficient PLL may not achieve adequate decompression with distraction alone [17].
4. Limitations of indirect decompression: The mean canal opening of 2.4 mm may be insufficient for patients with severe stenosis (canal diameter <6 mm). In such cases, direct decompression should be considered as an adjunct [19].

This study has several strengths, including a relatively large sample size ($n=63$) for a Nigerian cohort, the use of pre- and postoperative MRI for objective measurement, and the derivation of predictive equations with good explanatory power. However, limitations exist. The retrospective design introduces selection and information bias. The measurement of distraction using a calibrated ruler is subject to intraoperative variability. The study did not include a control group of patients who underwent direct decompression. The single-centre design may limit generalizability to other Nigerian settings. The absence of long-term clinical outcome data limits the ability to correlate radiological decompression with functional improvement.

Future prospective studies should correlate the radiological changes with clinical outcomes, including pain scores and functional disability. The role of preoperative ligamentous integrity assessment (e.g., MRI evidence of PLL disruption) in predicting the success of indirect decompression warrants further investigation. Comparative studies of indirect versus direct decompression are needed to define the optimal surgical strategy for different degrees of stenosis.

In conclusion, Pedicle screw distraction produces predictable, measurable increases in lumbar canal and foraminal dimensions. The derived predictive equations-Canal opening (mm) = $0.68 + 0.54 \times \text{Distraction (mm)}$ and Foraminal opening (mm) = $0.52 + 0.50 \times \text{Distraction (mm)}$ -provide a practical tool for estimating the expected decompression effect and guiding the magnitude of distraction during surgery. Indirect decompression via ligamentotaxis is a valuable technique for selected patients with lumbar stenosis, particularly those with intact posterior ligamentous complexes and mobile segments. However, direct decompression remains necessary for patients with severe stenosis or deficient ligamentous structures.

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