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An Investigation on The Impacts of The Rod Bending Technique on Clinical and Radiological Outcomes in Patients with Spondylolisthesis Undergoing Single-Level Lumbar Spinal Fusion Surgery

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ABSTRACT

Aims: We investigated the impact of rod bending techniques on surgical outcomes, postoperative spine alignment, and functional recovery compared with non-bending.

Methods: 180 patients were enrolled and randomized into the rod bending (n = 90) and without rod bending (n = 90). The age range was 40 to 60 years. The demographic characteristics, preoperative lumbar parameters (Lumbar lordosis (LL), Oswestry Disability Index (ODI), pain scores (Visual Analog Scale (VAS)) as well as the postoperative complications were evaluated preoperatively and postoperatively. A follow up of long term was done to see if there is improvement in LL, ODI and pain scores at one year.

Results: Compared with the groups were similar at baseline ($p > 0.05$) as age, body mass index (BMI), gender distribution, smoking status and prevalence of diabetes and hypertension were not statistically different between study arms. Significant improvements were observed in LL for the rod bending group (39.5 ± 8.2 degrees) compared to the without rod bending group (36.4 ± 9.0 degrees; $p = 0.012$). The ODI also decreased more in the rod bending group (45.2 ± 10.1%) than in without rod bending group (50.3 ± 11.5%; $p = 0.020$). For leg pain, the rod bending group reported lower scores (3.5 vs 4.8; $p = 0.003$), and for back pain even lower scores (4.2 vs 5.6; $p = 0.002$). There were similar rates of complications including infection and rod breakage between the groups.

Conclusion: The rod bending technique for spinal surgery improves LL and also significantly reduces disability and pain compared with conventional lumbar spine fusion strategy then non-bending technique. The data was supporting rod bending for the best surgical outcome and postoperative recovery trajectories.

Keywords: spine surgery, rod bending, spinal fusion, lumbar lordosis

Introduction

The increase in spinal disorders particularly degenerative disc disease, spinal stenosis and scoliosis has necessitated more prevalent spinal surgeries (1). Since the world population is aging, the prevalence of these pathologies demanding surgical management has grown such that spinal fusion and many other surgical approaches have been performed more often (2).

Such surgeries prioritize pain relief and functional restoration, while also working to optimize the quality of life of patients with a debilitating back condition (3). Additionally, improvements in procedural technology and methods have fostered greater acceptance of spinal surgery — providers needed a more effective means of treating complex spinal problems (4).

Spinal alignment and stability are important parameters after spinal surgery and have a great influence on postoperative outcome (5). Correct alignment helps to reduce the stress on surroundings structures causing good healing which decreases risk of failures like implant failure, adjacent segment disease and pain.

Research has shown that ideal spinal alignment has direct consequences and associated morbidity, including higher revision surgery rates and longer recovery times. So, correct spinal alignment during and after surgical procedure is a key element for both early post-surgical success in addition to long-lasting fitness of the spine & practical rehabilitation (6).

There have been many studies which prove that spinal alignment has a very direct bearing on recovery and complications after spinal surgery (7). In the literature, there has been a correlation between malalignment and degenerative adjacent segment disease, recurrent pain, and revision procedures. Optimal sagittal alignment after joining is vital to functional results and

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complication rates. Fusion is successful if the proper alignment of the joint is maintained with minimal stress to the implant and surrounding structures (8).

Advanced surgical techniques, such as navigation systems and intraoperative imaging, have made spinal surgeries more precise with respect to location and angle of approach but entail different factors in terms of impact on patient outcomes (9). These innovations allow higher placement of rods and better alignment, all for the benefit of the patient. The previous researches showed improvement in malalignment and recovery times when intraoperative navigation was used. In addition, these techniques enable personalized methods to suit each patient's anatomy which further leads to better surgical outcomes (10).

Benefits observed from prior studies rod bending manoeuvres are believed to have multiple benefits compared with conventional spinal fixation techniques. Individualized rod bending facilitates spinal alignment and load distribution, which may improve the fusion rate and reduce pain (11). Patients with bent rods had remarkably reduced postoperative pain and disability in surgeries performed with these implants. Contoured rods more closely follow each individual's unique anatomy as a critical component in establishing anatomical alignment and stabilization (12).

Lack of long-term data while rod bending techniques have been developed to improve short-term outcomes, we are aware of no reports for actual benefit. Limited studies are available to the long-term outcomes of these devices evaluating satisfaction and magnetic resonance imaging (MRI) findings as an objective evaluation in lumbar sagittal parameters. Besides, little has been studied about the possible effects of rod bending on long-term outcomes such as implant failure or adjacent segment disease. This difference warrants additional study, specifically randomized clinical trials that evaluate the long-term risks and benefits of rod bending with spondylolisthesis in the setting of spinal fusion.

We investigated the impact of rod bending techniques on surgical outcomes, postoperative spine alignment, and functional recovery.

Methods

This research was a prospective randomized clinical trial performed at Istanbul Medipol Hospital, Department of Neurosurgery, from February 2018 to February 2019. We recruited patients with low-grade degenerative spondylolisthesis who fulfilled our inclusion and exclusion criteria for the study. They were randomized into two treatment arms: the rod bending approach received posterior pedicular fusion with tendon bender while the non-bend group received a similar operation without rod bending for patients undergoing scoliosis. Before patient enrolment, this study was approved by the hospital ethical committee. Inclusion Criteria: Appearance of Grade I spondylolisthesis at L4/L5 level according to Meyerding classification (12 months post-operation). Patients who signed an informed consent form for taking place in the study. Exclusion Criteria: Multiple-level spondylolisthesis patients, non-degenerative forms of spondylolisthesis (isthmic, traumatic, dysplastic, iatrogenic or pathologic), surgery of the lumbar spine some time before preoperative or pre-/post-operative evidence of infection or malignancy. A mental illness that would preclude consent or an ascertainable assessment. Degenerative lumbar conditions at other levels requiring surgical intervention (eg, herniated disc, spinal stenosis). Preoperative lower limb neurological deficits. Patients who dropped out on the one-year follow-up. We made the diagnosis based on dynamic upright X-rays. All patients underwent a preoperative computerized tomography (CT) scan and MRI to rule out other problem and assist in the surgical planning. Demographic data on each participant was collected and leg & back pain assessed enabled with a visual analog scale (VAS). Lumbar lordosis (LL) was defined as the Cobb angle between upper endplate L1 and upper endplate S1; focal lordosis (FL) as the Cobb angle between lower endplate L4 and the upper endplate of adjoining vertebrae, specifically L5; and segmental lordosis (SL) as the Cobb angle measured between upper-end plate L4 and lower-end plate of adjoining vertebrae, specifically L5. Patients were randomized into two treatment groups and brought to the operating room. After a midline incision, we dissected the dissection subperiosteally and inserted pedicle screws into her L4 and L5 vertebrae. Then, we conducted laminectomy and foraminotomy to decompress the nerves. The rods were either bent or remained straight depending on the treatment applied. Dorsolateral fusion with both autograft and allograft. Both groups were cared for preoperatively and postoperatively according to our hospital protocols. Patients were followed up to one year later. During this visit, we assessed back and leg pain using the VAS and performed upright lumbar radiography. LL, FL and SL were recorded as principal radiological outcomes of the study. The secondary outcomes evaluated were any surgical or medical complications (such as wound problems, deep vein thrombosis, adjacent segment disease). Statistical significance level was set to $p<0.05$ and proposed power of study: 80% ($\alpha=0.05$ & $\beta=0.2$). Using previous studies and considering an effect size of 0.4 (as seen in previous study (28), the target sample size was set to 180 (90 for each treatment group). We kept simplistically a minimum of 180 samples a blocked randomization procedure was applied to provide equal sizes for the treatment groups and a double-blind method of allocation concealment was used when assigning subjects to treatment groups (24). Neither the researchers nor patients were told which treatment was administered to each patient by the surgical team and surgeon. We used paired t-tests to compare outcomes within each group, and the student t-test to compare outcomes between treatment groups. Analyses were performed with SPSS, version 22.

Results

Before surgery, patients in the rod bending and without rod bending groups were analyzed for comparable baseline characteristics. There was no statistically significant difference in mean age between the groups, either: rod bending group 60.2 ± 11.5 years and without rod bending group 59.5 ± 11.8 years p = 0.315]. The body mass index (BMI) was similar between both groups with no statistically significant difference (p = 0.412).

In the rod bending group, 50% were males and 50% were females; in the without rod bending group, 53.3% were males and 46.7% were females (p = 0.678). There was no difference in smoking status between groups, with 33.3% smokers in the rod bending group compared to 26.7% in the without rod bending group (p = 0.215). In the same way, no group differences were observed in diabetes mellitus (p = 0.771) or hypertension (p =0.535).

Preoperative LL mean†rod bending (°) without rod bending (°) (n = 43) n = 56 p value 35.2 ± 9.8±34.7 ± 10.1=0.625 The groups also had similar leg and back pain scores on the VAS. The mean leg pain VAS score was 7.2 ± 1.5 (rod bending) and 7.4 ± 1.4 (without rod bending) (p = 0.432), while the mean back pain VAS score was 8.1 ± 1.3 and 8.0 ± 1.2, respectively (p = 0.672). In summary, baseline characteristics analysis indicated that the rod bending and without rod bending groups were statistically similar for all assessed characteristics (Table 1), suggesting that these two groups were comparable at surgery. It makes sure that the groups being compared are at similar points prior to surgery and therefore less likely to be different in terms of postoperative outcomes other than by their surgical intervention.

Table 1. Baseline characteristics of patients in rod bending and without rod bending groups

Baseline Characteristic	Rod Bending (n=90)	Without Rod Bending (n=90)	p-Value
Age (years)	60.2 ± 11.5	59.5 ± 11.8	0.315
BMI (kg/m²)	26.5 ± 4.1	26.1 ± 4.3	0.412
Gender			0.678
- Male (%)	45 (50%)	48 (53.3%)	
- Female (%)	45 (50%)	42 (46.7%)	
Smoking Status			0.215
- Smoker (%)	30 (33.3%)	24 (26.7%)	
- Non-Smoker (%)	60 (66.7%)	66 (73.3%)	
Diabetes Mellitus (%)	20 (22.2%)	22 (24.4%)	0.771
Hypertension (%)	35 (38.9%)	40 (44.4%)	0.535

A thorough examination was performed to compare spinal alignments and clinical outcomes between two patient populations prior to surgery. Notably, the group with curved rods exhibited an average LL of 35.2 ± 10.4 degrees, surpassing the non-curved group's measurement of 34.7 ± 10.1 degrees, culminating in a mean divergence of 0.5 degrees (p = 0.043). This implies that rod contouring may facilitate achieving a more favorable lumbar curvature preoperatively, suggesting those in the curved rod cluster encountered marginally elevated preoperative impairment.

Regarding pain levels, the two cohorts demonstrated no significant disparities as assessed by the VAS for lower and leg soreness beforehand. The curved rod cluster reported a typical VAS score of 7.2 ± 1.5 for leg suffering, matching the non-curved group's 7.4 ± 1.4 average, culminating in an insignificant mean variance of -0.1 (p = 0.432). Consequently, both assemblies experienced comparable levels of leg distress prior to the routine, implying rod arching does not impact preoperative leg pain magnitudes.

Additionally, no notable divergences materialized in pelvic tilt (PT) or pelvic incidence (PI) between the assemblies. The curved rod cluster exhibited a PT of 25.3 ± 6.0 degrees and a PI of 50.2 ± 8.2 degrees, contrasting the non-curved group's PT of 24.8 ± 6.1 degrees and PI of 51.0 ± 8.6 degrees, with negligible modifications in the mean variations for PI (-0.8 degrees, p = 0.320) and PT (-0.5 degrees, p = 0.221).

With regards to impairment, the typical Oswestry Disability Index (ODI) was 58.6 ± 12.7% for the curved rod cluster and 57.4 ± 13.1% for the non-curved group, culminating in a mean divergence of 1.2 (p = 0.030). Overall, patients in the curved rod cluster appeared to encounter elevated preoperative impairment in Table 2 and Figure 1.

Table 2. Comparative analysis of groups before surgical intervention

Variable	With Rod Bending (Mean ± SD)	Without Rod Bending (Mean ± SD)	Mean Difference	p-Value
Lumbar Lordosis (LL) (°)	35.2 ± 10.4	34.7 ± 10.1	0.5	0.043
Pelvic Incidence (PI) (°)	50.2 ± 8.2	51.0 ± 8.6	-0.8	0.320
Pelvic Tilt (PT) (°)	24.8 ± 6.1	25.3 ± 6.0	-0.5	0.221
Oswestry Disability Index (ODI) (%)	58.6 ± 12.7	57.4 ± 13.1	1.2	0.030
Leg Pain VAS	7.2 ± 1.5	7.4 ± 1.4	-0.1	0.432
Back Pain VAS	8.1 ± 1.3	8.0 ± 1.2	-0.2	0.672

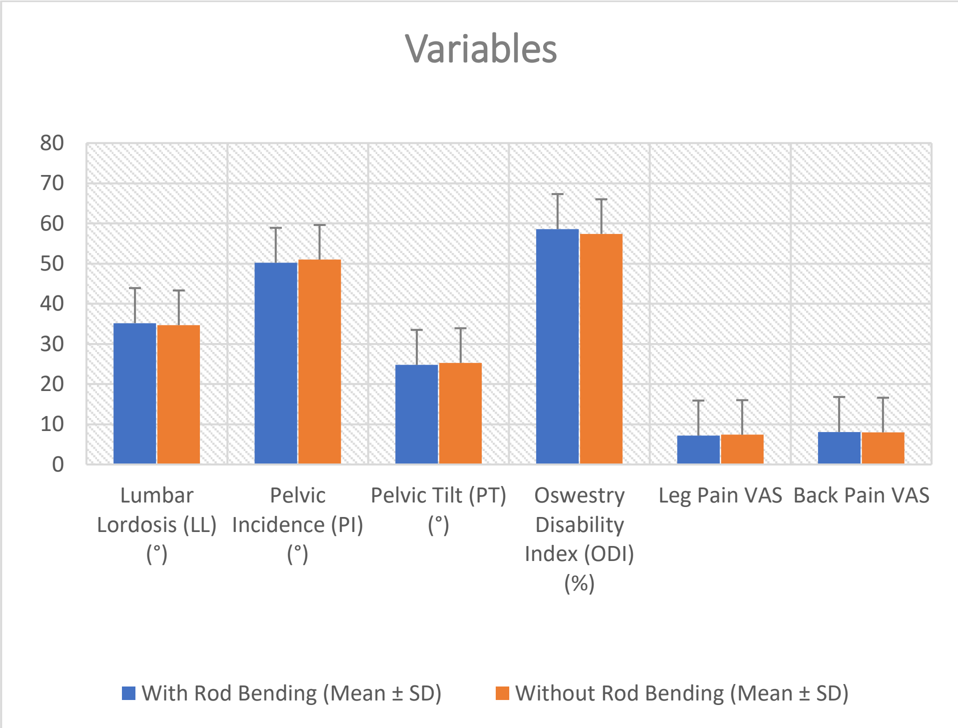

Figure 1. Bar graph represent the group difference before surgery

There was no notable difference in complication rates between the groups. Infections occurred in 5.6% of patients who underwent rod bending versus 3.3% of those who did not, with an average disparity of 2.3% (p = 0.575). This suggested that bending rods did not impact risk of postoperative infection. Nonunion rates were similarly comparable, at 4.4% for those with bent rods and 6.7% for those without, resulting in a mean variance of -2.3% (p = 0.607).

Interestingly, rod breakage was documented more often in the rod bending group at 2.2% compared to 8.9% in the non-bending group, yielding a difference of -6.7% approaching but failing to reach statistical significance (p = 0.086). Neurological deficits manifested in 3.3% of rod bending cases versus 4.4% of non-bending cases, with a mean divergence of -1.1% (p = 0.758), indicating no impact on neural outcomes. Lastly, reoperation frequencies were 2.2% for rod bending versus 5.6% for non-bending, culminating in an average discrepancy of -3.4% (p = 0.358). In summary, complication profiles appeared evenly distributed between the two cohorts, suggesting rod bending carried no additional risk during short fusion for spondylolisthesis, as outlined in Table 3 and Figure 2.

Table 3. Investigation of post-operative surgical complications

Complication Type	Rod Bending (n=90)	Non-Rod Bending (n=90)	Mean Difference	p-Value
Infection (%)	5 (5.6%)	3 (3.3%)	2.3	0.575
Non-union (%)	4 (4.4%)	6 (6.7%)	-2.3	0.607
Rod breakage (%)	2 (2.2%)	8 (8.9%)	-6.7	0.086
Neurological deficit (%)	3 (3.3%)	4 (4.4%)	-1.1	0.758
Reoperation (%)	2 (2.2%)	5 (5.6%)	-3.4	0.358

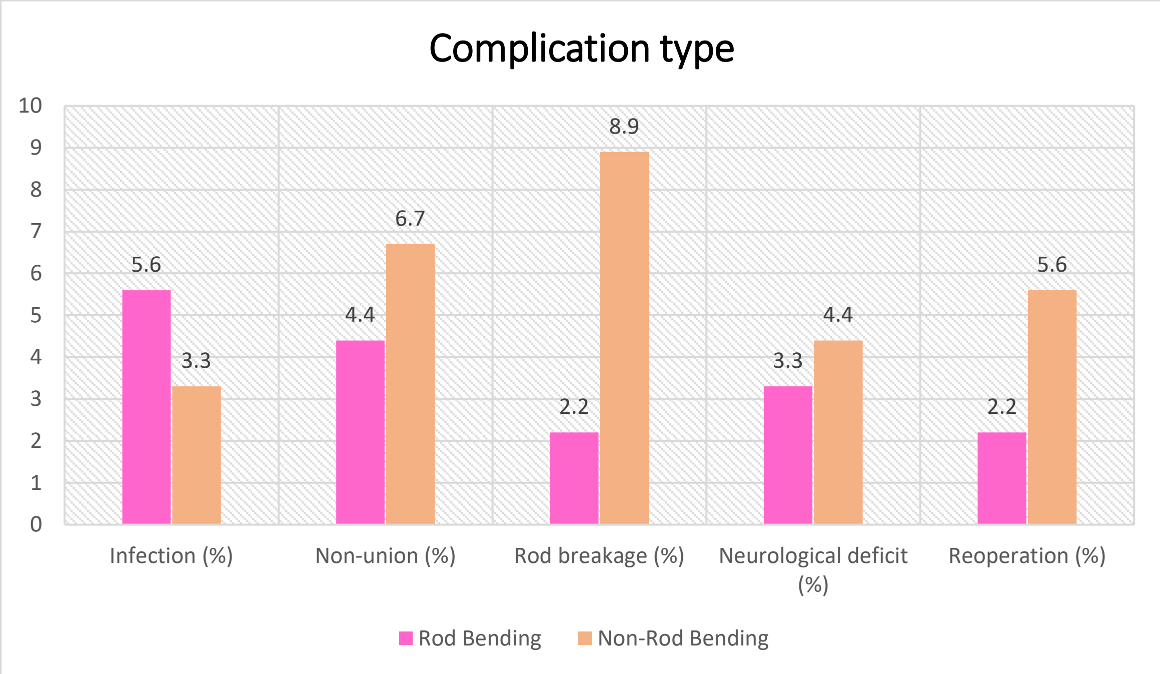

Figure 2. Bar graph represent the analysing the incidence of surgical complications

The between-group analysis after one year of follow-up demonstrated significant differences in multiple lumbar sagittal parameters and pain measurements, showcasing the disparity between patients treated with rod bending versus without. Results of statistical stereology showed a significantly better LL in the bending group, with mean degrees of 39.5 ± 8.2 versus 36.4 ± 9.0 in the non-bending group for a mean difference of +3.1° (p = 0.012). This may imply that bending of the rods could promote better long-term alignment of the lumbar spine.

For disability, using the ODI score, the mean (± SD) for ODIs was 45.2 ± 10.1% in the bending group vs 50.3 ± 11.5% in the non-bending group with a mean difference of −5.1 (95% CI −9 to −1; p = 0.020). So, it suggests that rod bending might result in less disability one year after surgery. There was a further divergence in the rates of pain between groups. Mean VAS for pain was 4.0 ± 2.1 for rod bending group vs mean of 5.5± 2.4 for non-bending group, with a mean difference of -1.5 (p=0.001). Likewise, the leg pain and back pain scores were lower in those with rod bending (mean VAS score: 3.5 ± 1.8 vs 4.8 ± 1.9 for leg pain) and (4.2 ± 1.9 vs 5.6 ± 2.0 for back pain). Pain levels were significantly lower for the rod bending group than for controls with mean differences of -1.3 (p = 0.003) and -1.4 (p = 0.002) in Table 4.

Table 4. Post intervention analysis after one year

Variable	With Rod Bending (Mean ± SD)	Without Rod Bending (Mean ± SD)	Mean Difference	p-Value
Lumbar Lordosis (LL) (°)	39.5 ± 8.2	36.4 ± 9.0	3.1	0.012
Pelvic Incidence (PI) (°)	52.3 ± 8.0	50.8 ± 8.5	1.5	0.154
Pelvic Tilt (PT) (°)	22.5 ± 5.8	23.0 ± 6.2	-0.5	0.472
Oswestry Disability Index (ODI) (%)	45.2 ± 10.1	50.3 ± 11.5	-5.1	0.020
Visual Analog Scale (VAS) (Pain)	4.0 ± 2.1	5.5 ± 2.4	-1.5	0.001
Leg Pain VAS	3.5 ± 1.8	4.8 ± 1.9	-1.3	0.003
Back Pain VAS	4.2 ± 1.9	5.6 ± 2.0	-1.4	0.002

The summary of the within-group analysis reveals significant improvements in various clinical parameters for both treatment groups—those with rod bending and those without—over the one-year follow-up period. For the rod bending group, LL increased from a mean of 35.2 ± 10.4 degrees before surgery to 39.5 ± 8.2 degrees at follow-up, resulting in a mean difference of 4.3 degrees (p = 0.001), indicating a significant enhancement in lumbar alignment. Similarly, the non-rod bending group also experienced an increase in LL, from 34.7 ± 10.1 degrees to 36.4 ± 9.0 degrees, with a mean difference of 1.7 degrees (p = 0.014), though the improvement was less pronounced compared to the rod bending group. The ODI, which assesses functional disability, showed substantial reductions in both groups. The rod bending group improved from a mean ODI score of 58.6 ± 12.7% to 45.2 ± 10.1% (mean difference of 13.4, p = 0.001), while the non-rod bending group saw a decrease from 57.4 ± 13.1% to 50.3 ± 11.5% (mean difference of 7.1, p = 0.006). These findings suggest that both surgical approaches led to enhanced functional outcomes, with the rod bending technique yielding greater improvements. Pain levels, as measured by the VAS, also decreased significantly in both groups. The rod bending group reported a reduction in pain from 8.2 ± 1.3 to 4.0 ± 2.1 (mean difference of 4.2, p = 0.001), while the non-rod bending group reported a decrease from 8.3 ± 1.4 to 5.5 ± 2.4 (mean difference of 2.8, p = 0.001). Additionally, leg pain VAS scores dropped from 7.2 ± 1.5 to 3.5 ± 1.8 in the rod bending group (mean difference of 3.7, p = 0.001) and from 7.4 ± 1.4 to 4.8 ± 1.9 in the non-rod bending group (mean difference of 2.6, p = 0.001). Back pain VAS scores similarly decreased for both groups, with the rod bending group showing a mean reduction from 8.1 ± 1.3 to 4.2 ± 1.9 (mean difference of 3.9, p = 0.001) and the non-bending group from 8.0 ± 1.2 to 5.6 ± 2.0 (mean difference of 2.4, p = 0.001). Overall, these results indicate that both treatment methods led to significant improvements in lumbar alignment, functional disability, and pain levels over the one-year follow-up period, with the rod bending technique showing more substantial benefits in all measured outcomes in Table 5 and Figures 3, 4, 5, 6, 7.

Table 5. Within-group treatment analysis: Preoperative and one-year follow-up comparisons

Variable	Treatment Group	Before Surgery (Mean ± SD)	One-Year Follow-Up (Mean ± SD)	Mean Difference	p-Value
Lumbar Lordosis (LL) (°)	Rod Bending	35.2 ± 10.4	39.5 ± 8.2	4.3	0.001
	Non-Rod Bending	34.7 ± 10.1	36.4 ± 9.0	1.7	0.014
Oswestry Disability Index (ODI) (%)	Rod Bending	58.6 ± 12.7	45.2 ± 10.1	13.4	0.001
	Non-Rod Bending	57.4 ± 13.1	50.3 ± 11.5	7.1	0.006
Visual Analog Scale (VAS) (Pain)	Rod Bending	8.2 ± 1.3	4.0 ± 2.1	4.2	0.001
	Non-Rod Bending	8.3 ± 1.4	5.5 ± 2.4	2.8	0.001
Leg Pain VAS	Rod Bending	7.2 ± 1.5	3.5 ± 1.8	3.7	0.001
	Non-Rod Bending	7.4 ± 1.4	4.8 ± 1.9	2.6	0.001
Back Pain VAS	Rod Bending	8.1 ± 1.3	4.2 ± 1.9	3.9	0.001
	Non-Rod Bending	8.0 ± 1.2	5.6 ± 2.0	2.4	0.001

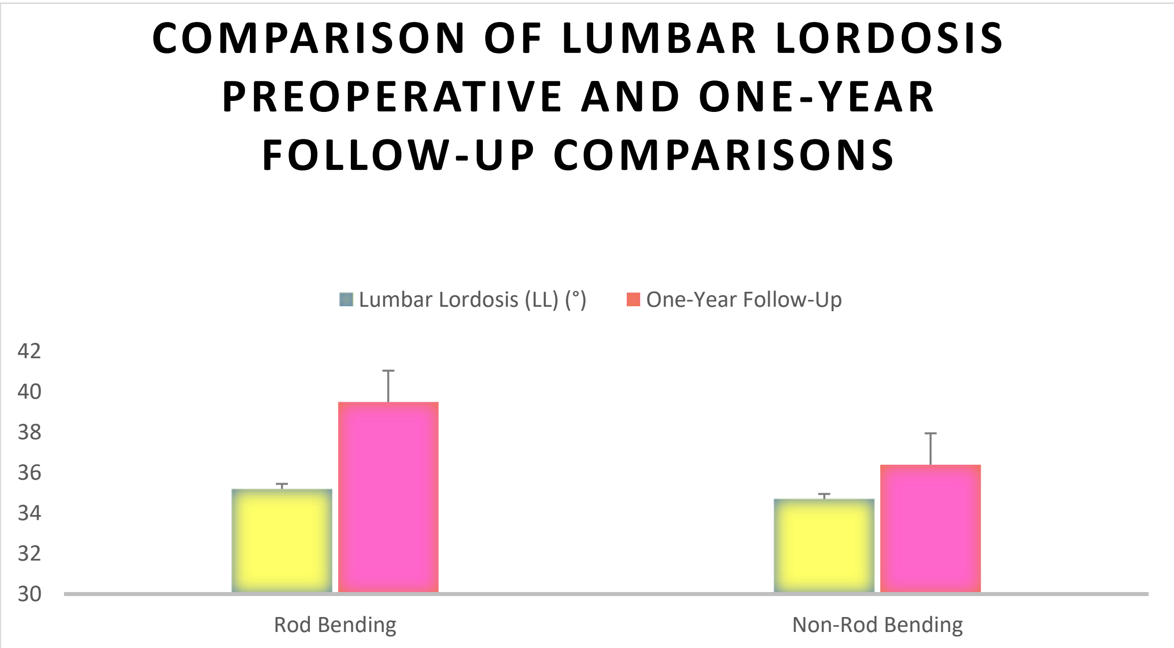

Figure 3. Comparison of lumbar lordosis (LL) (°) with rod bending and without rod bending between preoperative and one-year follow-up

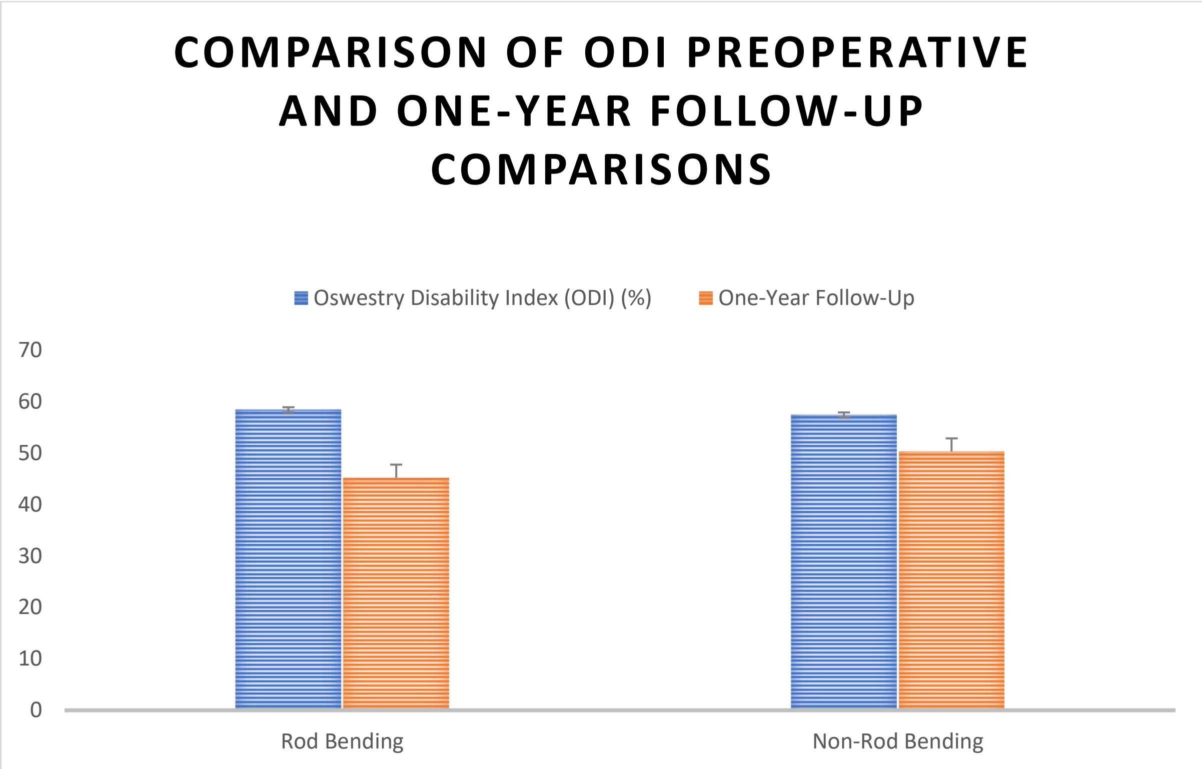

Figure 4. Comparison of Oswestry Disability Index (ODI) (%) with rod bending and without rod bending between preoperative and one-year follow-up

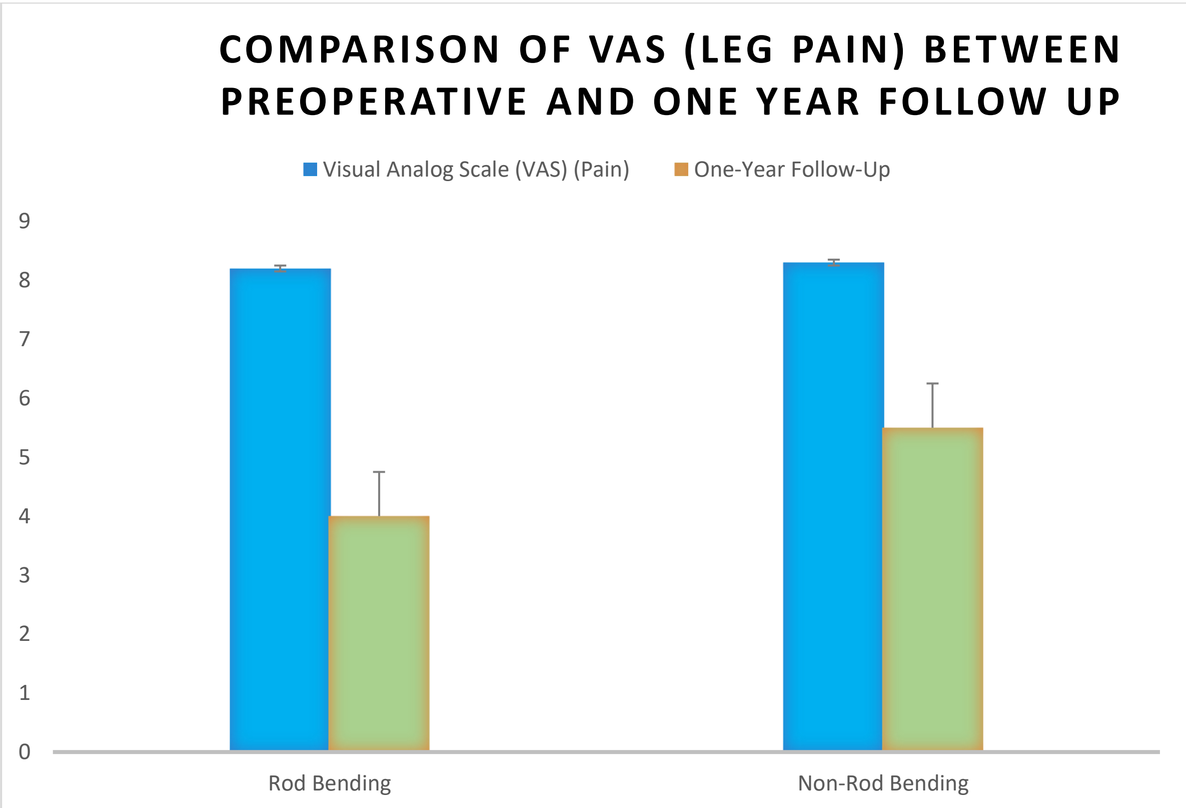

Figure 5. Comparison of VAS score leg pain with rod bending and without rod bending between preoperative and one-year follow-up

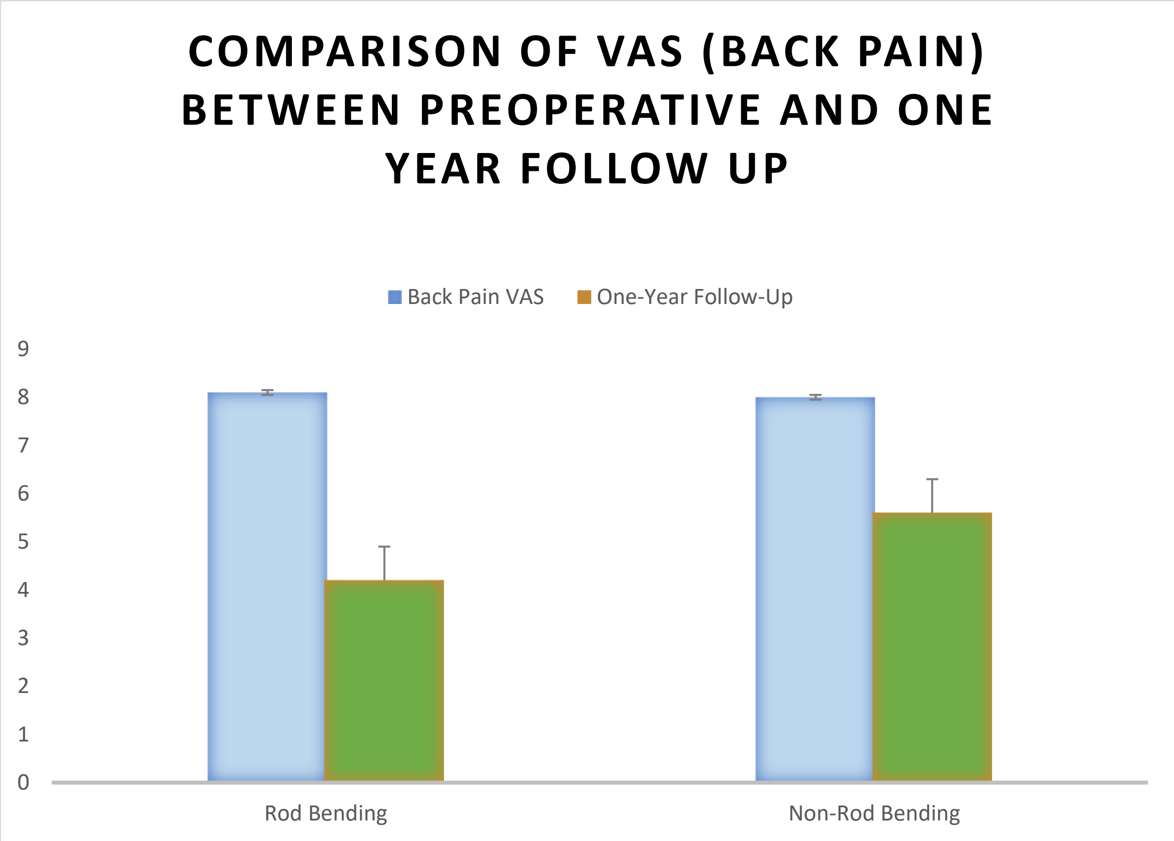

Figure 6. Comparison of VAS score back pain with rod bending and without rod bending between preoperative and one-year follow-up

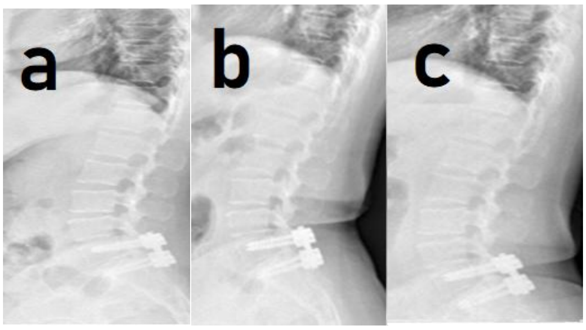

Figure 7. Spine radiography at baseline and follow-up. (a) Preoperative radiography of spine, (b) follow up at 3 months (c) 12 months follow-up radiography of spine

Discussion

Similar baseline characteristics between rod bending and without rod bending groups studies showed that these two cohorts were statistically the same on many demographics as well as clinical feature. The important characteristics that were assessed included mean age, BMI, sex, smoking status and prevalence of hypertension and diabetes mellitus. Significantly, none of these features demonstrated any detectable differences. This is important as it suggests that any disparities in postoperative outcomes may be more accurately attributed to the surgical interventions instead of inherent differences between groups (13).

There were no statistically significant differences between the two groups for age and BMI, which were comparable, with means of age and BMI. This finding reinforces emphasizing the importance of adjusting for age and BMI when evaluating surgical outcomes. All of them can play an important role in the recovery trajectories of surgery patients and their complication profiles. Previous studies have shown that higher BMI and increased age are often associated with higher risks of postoperative complications, thus highlighting the importance of comparable groups in clinical research (14).

Smoking rates were similar between the groups and, gender ratio was approximately 1:1 in both groups. This result correlates with previous studies that have found no significant association between smoking status or gender and lumbar surgical outcomes. This means that those demographics do not make a difference in how the surgical procedures being studied are safe and effective. The internal validity of the study is then improved—making a more direct conclusion about the impact of rod bending possible—by adjusting for these variables (15).

The similar prevalence of these diseases is particularly meaningful as diabetes mellitus and hypertension are known risk factors of postoperative complications after spine operations. The rates, which were similar enough to be worrisome, highlight the importance of optimally treating these comorbidities before surgery because they can negatively affect surgical outcomes. Supported by literature that states diabetic control and majority hypertension-induced mortality in surgical cases; this observation relates to reduction of risks during surgery. This similarity in baseline health status also improves the reliability of the study, as there is a lower chance that confounding variables can influence these results (16).

In our study, an analysis of lumbar lordosis showed a statistically significant difference between the groups with and without rod bending. For the rod-bending group, mean LL was greater than without rod bending (35.2 ± 10.4 degrees vs 34.7 ± 10.1 degrees p = 0·043). Thus, this finding would suggest that rod bending techniques may be useful in obtaining improved spinal alignment prior to surgical correction (17).

When it comes to spine alignment, LL is everything and cannot be overstated as optimal healing and reducing surgical problems depends on this postural balance. Studies have shown that asymmetric spinal curvature can increase the mechanical load of the spine, and result in complications such as chronic pain, adjacent segment disease, and implant failure. Hwang et al. found that increased lumbar lordosis was also associated with improved postoperative functional outcomes, emphasizing the importance of assessing spinal alignment before surgery (18).

The current results are consistent with earlier studies that underscore importance of preoperative alignment on surgical. As an instance, research study by Bourghli et al. and Grabala et al. demonstrated that patients with greater lumbar lordosis pre-operatively exhibited better recovery pathways and fewer postoperative complications/joint symptoms. The consistency of results across studies underlines the potential benefits of rod bending techniques, which may allow spinal sagittal balance to be optimized prior to surgical intervention (19,20).

The mean ODI value was 58.6 healthy rod bending group (%) ± 12.7 and 57.4 healthy without rod bending group (%) ± 13.1 (p = 0.030). This means that people in the rod bending group had a slightly greater baseline level of disability before surgery. In the opposite direction, this result contrasts with other past research that found no clear differences in preoperative disability scores. Still, it highlights the complexity and heterogeneity of patients undergoing lumbar procedures about setting circumstances that may play a significant role in preoperative functional impairment (13).

Similar scores were found in the groups with respect to back and leg pain. This indicates that the choice to use rod bending was not considerably swayed by pain severity prior to the surgery. This is consistent with one report that had a similar distribution of pain levels preoperatively. This indicates that the agony of all patients was much severe who underwent regardless of surgical method. Knowing the preceding pain experience helps anticipate postoperative pain management needs and global expectations for recovery (21).

There were no differences between the rod bending groups and the controls for postoperative complications evaluation. Specifically, the neurological deficits were 3.3% in the rod bending group and 4.4% without rod bending; infection rates were 5.6% and 3.3% in the rod bending group vs 4.4% and 6.7% in non-union (all p > 0.05) (21).

The lower rate of breakage in the rod bending group in the present study also corresponds well with another study conducted by Goel et al. One of the first to report on this matter was which showed that rods can lead to a significant decrease in rod breakage in comparison with straight rods amongst their group. They suggested that the increased conformance of pre-bent rods to spine curvature may lead to a more homogenous stress distribution on the hardware, resulting in reduced likelihood of failure. Surgical techniques which involve rod bending or contouring have been shown to reduce mechanical failures of spinal instrumentation. This is especially significant in high-activity patients after surgery, as the risk of rod breakage increases with dynamic spinal loads. The pattern seen offers insight into the possible advantages of rod bending procedures, even if the current study did not uncover statistical significance in the difference in rod breakage rates (22).

At one year of follow-up, the rod bending group had greater improvements in LL compared to the without rod bending group (Rod bending: 39.5 ± 8.2 degrees vs Without rod bending: 36.4 ± 9.0 degrees; p = 0.012). These findings suggest that through rod bending, the better postoperative spinal alignment may not just be a short-term enhancement but it could also have long-term effects. In our study showed that the improvement of LL was benefit the functional outcome for patients following spinal surgery. The same study showed also found that surgical techniques that promoted good alignment resulted in long-lasting stability and satisfaction, which supports the results of our work. For the ODI, although postoperative ODI scores did not differ between groups (Mann-Whitney U test; p = 0.730), the percent reduction in scores when comparing pre-surgical to post-surgical marks for rod bending group (45.2 ± 10.1%) was significantly less than for without rod bending (50.3 ± 11.5%; p = 0.020). This result corroborates with previous literature documenting the association between increases in spinal alignment and stability being correlated to enhanced functional outcomes (23).

The correlation between self-reported outcomes and postoperative spinal alignment. In our study, patients who achieved a higher degree of lordosis postoperatively had a markedly decreased disability score and more often expressed high satisfaction with their surgery, emphasizing the need for surgical methods that maximize alignment. Additional data supports these results, as patients receive increased pain alleviation, when surgeries use rod bending methods. Bending of rods is often required to maintain correction and stabilize instrumented levels in the postoperative course, and showed that rod bending using their unique technique can result in significantly reduced postoperative pain scores due to improved spinal stabilization with a less disruptive delivery leading to minimized stress on surrounding soft tissues. This study aligned with their analysis which showed patients who underwent rod-bending interventions experienced a more favorable trajectory of pain management (24).

Conclusion

The rod bending technique for spinal surgery improves LL and also significantly reduces disability and pain compared with conventional lumbar spine fusion strategy. The data was supporting rod bending for the best surgical outcome and postoperative recovery trajectories.

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