

# Comparison of clinical and radiological results of dynamic and rigid instrumentation in degenerative lumbar spinal stenosis

## ABSTRACT

**Objective:** Lumbar spinal stenosis is defined as a clinical syndrome characterized by neurogenic claudication or radicular pain due to the narrowing of the spinal canal or neural foramen and the compression of its neural elements. Surgical treatment is applied to decompress the neural structures. In some cases, transpedicular instrumentation and fusion may also be applied. In this study, we aimed to investigate and compare the preoperative and postoperative, clinical and radiological aspects of patients with lumbar spinal stenosis who underwent lumbar instrumentation using a polyetheretherketone (PEEK) rod or a titanium rod.

**Materials and Methods:** In this study, the files of 293 patients who underwent posterior lumbar transpedicular stabilization between January 2015 and February 2018 in the Neurosurgery Clinic of Ümraniye Training and Research Hospital were reviewed retrospectively. Patients who did not meet the study criteria were excluded, and 127 patients who met the criteria and underwent posterior lumbar transpedicular stabilization due to lumbar spinal stenosis and/or lumbar degenerative disc disease were retrospectively reviewed. The patients were divided into two groups, dynamic and rigid, according to the rod types used. The two groups were compared using various postoperative clinical and radiological parameters.

**Results:** The demographic data, surgical data, Visual Analog Scale-Oswestry Disability Index (VAS-ODI) data, and radiological data of both groups were carefully examined. There were 63 patients in the rigid group and 64 patients in the dynamic group. The age range in both groups was from 30 to 78 years, with a mean age of 56.44 years; 99 of the cases were female and 28 were male. The analysis of the participants' demographic data showed no significant differences between the two groups. Compared with the preoperative data, the postoperative evaluations revealed a significant decrease in VAS and ODI, but no significant difference was observed between the two groups. There was no difference between the two groups in terms of duration of surgery, follow-up time, operating distances, hospitalization duration, pseudoarthrosis, or fusion. Regarding the total and segmental range of motion, the affection was less in the dynamic group, which allowed for more movement. While there was no difference in disc height index between the two preoperative groups, it was observed that it was better maintained in the rigid group in the postoperative long term. Regarding foraminal height (FH), there was no difference between the two groups in the preoperative and early postoperative periods, but in the long term, FH was better maintained in the dynamic group. The long-term follow-ups revealed that adjacent segment disease (ASD) had developed in 19 patients in the rigid group, whereas ASD developed in only nine patients in the dynamic group. Based on these results, the probability of developing significant ASD in the rigid group was higher.

**Conclusion:** Previous experience with PEEK rod systems has demonstrated physiological spine movement, increased fusion rates, minimal complications, reduction in adjacent segment degeneration, and biomechanical compatibility. Although further long-term studies are needed and the cost of PEEK systems is likely to be a barrier, the results of the present study support the use of PEEK rods and other dynamic systems in spinal surgery.

**Keywords:** Dynamic instrumentation, lumbar spinal stenosis, polyetheretherketone rod

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## INTRODUCTION

Lumbar spinal stenosis is defined as a clinical syndrome characterized by neurogenic claudication or radicular pain due to the narrowing of the spinal canal or neural foramen and the compression of its neural elements.<sup>[1]</sup> The narrowing may be caused by bone hypertrophy, ligament hypertrophy, disc protrusion, spondylolisthesis, or a combination thereof.<sup>[2]</sup>

The efficacy of surgical treatment is indisputable in cases that do not respond to conservative treatment and show progressive findings. The basis of surgical treatment is the decompression of neural structures.<sup>[2]</sup> Depending on the case, transpedicular instrumentation and fusion can also be performed.<sup>[3]</sup> However, the instrumentation of patients increases the patient's vulnerability to additional complications such as adjacent segment and pseudoarthrosis.<sup>[4]</sup> Therefore, physicians have been interested in finding innovative approaches to spinal surgery, and different techniques have been studied.

In this study, we aimed to investigate and compare the preoperative and postoperative, clinical, and radiological aspects of patients with lumbar spinal stenosis who underwent lumbar instrumentation using a polyetheretherketone (PEEK) rod or a titanium rod.

## MATERIALS AND METHODS

This study included 127 randomly selected patients who underwent posterior lumbar transpedicular stabilization for the treatment of symptomatic lumbar degenerative spine with or without spinal stenosis between January 2015 and February 2018. Insufficient data, advanced spondylolisthesis (Grade > 1), degenerative scoliosis (> 15°), more than four levels of instrumentation, previous history of lumbar surgery, and posterior transpedicular stabilization (PSE) for other reasons (e.g., trauma, advanced osteoporosis, infection, tumor, congenital, etc.) were not included in the study. A standard polyaxial screw was used as the bone instrument interface and based on the type of rod, patients were categorized into group 1 (rigid titanium rod) or group 2 (dynamic PEEK rod). In group 1, posterolateral fusion was performed for all cases. In group 2, fusion was not performed.

The demographics of the patients were summarized as follows: age, gender, symptoms, symptom duration, body mass index, comorbidities (e.g., smoking, hypertension, and diabetes); surgical and radiological parameters; preoperative and postoperative evaluations at 3<sup>rd</sup>, 6<sup>th</sup>, and 12<sup>th</sup> months (i.e., segmental range of motion [ROM], total ROM, disc height index [DHI], foraminal height [FH], adjacent segment disease [ASD], pseudoarthrosis, and fusion rate).

## Statistical analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences SPSS 25.0 (IBM Corp., Armonk, NY, USA), which was used on a Windows operating system. In evaluating the study data, a *t*-test was applied to compare the quantitative data and the descriptive statistical methods (i.e., mean and standard deviation). A Chi-squared test was used to compare the qualitative data. The results were evaluated at a 95% confidence interval and a significance level of  $P < 0.05$ .

## RESULTS

The study participants included 99 females (78%) and 28 males (22%); the mean age was 56.44 years (age range 30–78 years). There was no statistically significant difference between the mean age in the two groups ( $P > 0.05$ ). The demographic information and comorbidities of the patients are summarized in Table 1.

The duration of surgery, hospitalization duration, and the number of surgical levels performed in both groups are summarized in Table 2.

There were 86 and 104 operated levels in group 1 and group 2, respectively. There was no statistically significant difference between the two groups in duration of surgery and postoperative hospitalization ( $P > 0.05$ ) [Table 2]; 190 levels in 127 cases were operated on (104 levels in group 1 and 86 levels in group 2). L4–L5 was the most frequently operated

**Table 1: The list of demographics and comorbidities**

Parameter (mean)	Group 1	Group 2	P (t-test)
Age	57.65±9.9	55.25±10.6	0.191
Gender (male/female) (%)	12/51 (19)	16/48 (25)	0.448
BMI (kg/m <sup>2</sup> )	28.7±3.7	29.4±4.5	0.320
Smoking (%)	15 (24)	16 (25)	0.875
Diabetes mellitus (%)	15 (24)	17 (27)	0.720
Hypertension (%)	32 (51)	29 (45)	0.536

BMI: Body mass index

**Table 2: List of surgical parameters**

Surgical parameters	Group 1	Group 2	P (χ <sup>2</sup> )
Duration of surgery (min)	204.44±49.6	205.63±53.7	0.898
Hospitalization (day)	3.22±1.1	3.23±0.8	0.945
Number of surgical levels			
1 level	43	36	0.051
2 levels	17	16	
3 levels	3	12	
Number of each segment			
L1-2	2	1	
L2-3	7	16	
L3-4	25	34	
L4-5	44	52	
L5-S1	8	1	

level. Fusion was detected in 36 cases (57%) and 30 cases (47%) in groups 1 and 2, respectively ( $P = 0.247$ ).

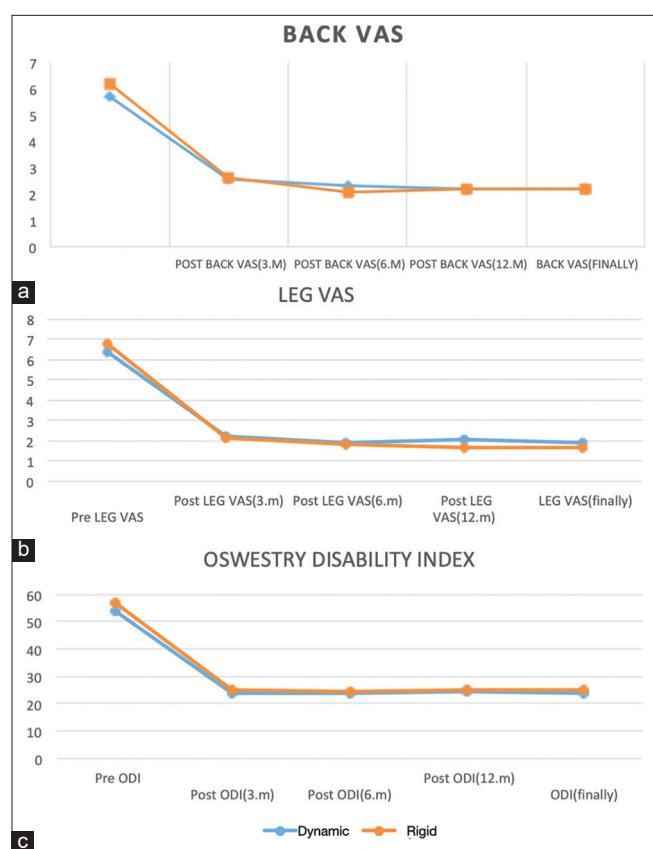
Early complications were observed in 17 cases: five (8%) in group 1 and 12 (19%) in group 2 ( $P = 0.016$ ). Four cases (6.4%) in group 1 and eight cases (13%) in group 2 required reoperation. The complications in the two groups are summarized in Table 3.

The results showed that the preoperative and postoperative lumbar-leg VAS and ODI values in the rigid group and the dynamic group were significantly decreased. The preoperative and postoperative measurements showed no significant difference in VAS and ODI values between the two groups [Figure 1].

**Table 3: List of early and late complications**

Complications	Group 1 (%)	Group 2 (%)
Early complications	5 (8)	12 (19)
Screw malposition (early period)	1 (1.6)	4 (6.2)
Superficial site infection	2 (3.2)	5 (7.8)
Epidural hematoma	1 (1.6)	0
CSF fistula	1 (1.6)	3 (4.7)
Late complications	27	14
ASD	19 (30)	9 (14)
Pseudoarthrosis	8 (13)	5 (8)

ASD: Adjacent segment disease, CSF: Cerebrospinal fluid

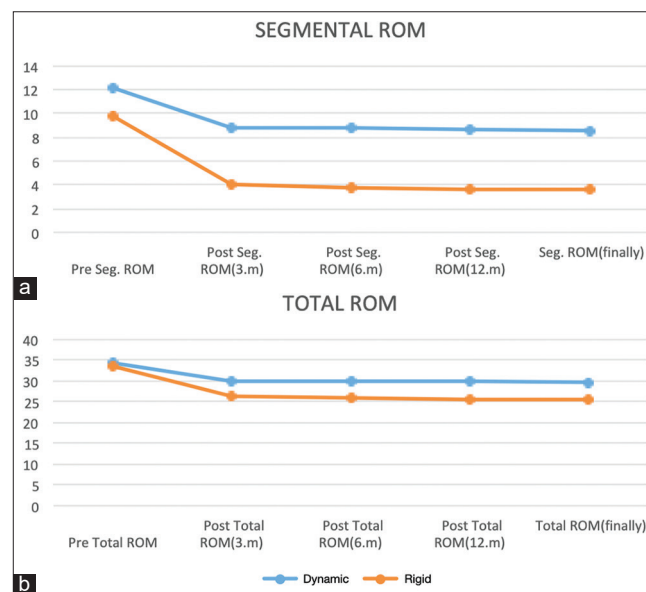


**Figure 1: Comparison of low back VAS scores (a), leg VAS scores (b) and ODI scores (c) of dynamic and rigid rods in preoperative, postoperative 3<sup>rd</sup>, 6<sup>th</sup>, 12<sup>th</sup> month and late follow-up**

The comparison of the preoperative segmental ROM values of the rigid group and the dynamic group patients showed  $P = 0.31$ . There was no significant difference in the preoperative segmental ROM values of the patients in either group. The preoperative–postoperative comparison showed  $P < 0.001$ . The postoperative segmental ROM was significantly decreased in both groups. The comparison of the postoperative segmental ROM in both groups showed  $P < 0.001$ . The segmental ROM values of the patients in the dynamic group were significantly higher than in the rigid group, which indicated that it was better maintained in the former group.

The comparison of preoperative total ROM values in the rigid group and the dynamic group resulted in  $P = 0.77$ . There was no statistically significant difference in the preoperative total ROM values of the patients in either group. The preoperative and postoperative comparisons showed  $P = 0.001$  and  $P = 0.007$ , respectively. The postoperative total ROM was significantly decreased in both groups. In the last follow-up, the comparison of the postoperative total ROM in both groups showed  $P = 0.042$ . The total ROM values in the dynamic group were significantly higher than in the rigid group, which indicated that it was better maintained [Figure 2].

The preoperative and postoperative DHI values of the patients in the rigid and dynamic groups were  $P = 0.48$  and  $P = 0.94$ , respectively. Accordingly, the preoperative and postoperative DHI changes in the rigid group and dynamic group were not significant. That is, there was no significant change in preoperative and postoperative DHI values in either



**Figure 2: Comparison of segmental ROM (a) and total ROM (b) of dynamic and rigid rods in preoperative, postoperative 3<sup>rd</sup>, 6<sup>th</sup>, 12<sup>th</sup> month and late follow-up**

group. However, although there was no difference in the preoperative DHI, it was found to be statistically significantly higher in the postoperative rigid group.

The comparison of the preoperative and postoperative FH values in the rigid and dynamic groups showed that the values were significantly increased postoperatively in both groups. However, no statistically significant difference was observed between the preoperative and postoperative groups [Figure 3].

### Postoperative adjacent segment disease

ASD refers to any changes in motion segments above and below the surgical site, such as disc herniation, spinal stenosis, proximal junction kyphosis, and so on. Patients with radiological and clinical findings of ASD and patients who reoperated for ASD were recorded. ASD was detected radiologically and clinically in 19 (30%) patients in the rigid group during the entire follow-up period. In the dynamic group, ASD was detected in nine (14%) patients during the entire follow-up period. Four (6.3%) of these patients in the rigid group and five (7.8%) of these patients in the dynamic group underwent reoperation to treat ASD. The number and rate of cases related to the levels of ASD are shown in Table 4.

The comparison of the data on the two groups in our study yielded  $P = 0.028$ . According to this result, a statistically significant difference was found between the two groups in terms of ASD ( $P < 0.05$ ). Therefore, according to our results, the probability of ASD in cases in which the rigid system was applied was significantly higher (30%) than in the cases in which the dynamic system was applied (14%).

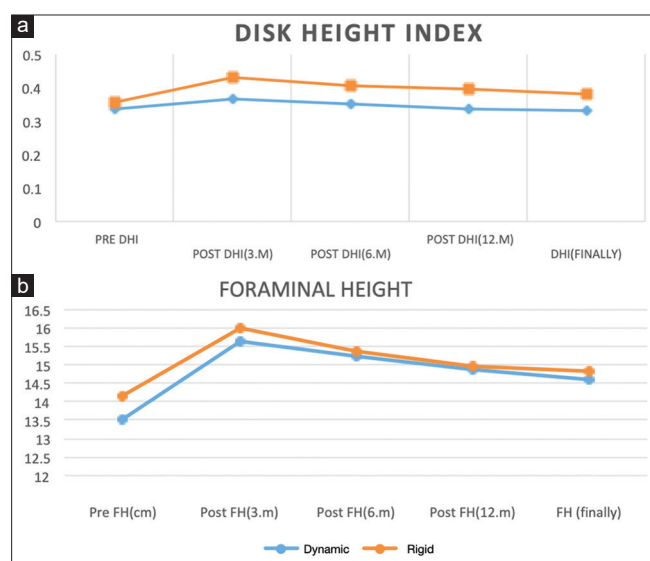


Figure 3: Comparison of disk height index (a) and foraminal height (b) of dynamic and rigid rods in preoperative, postoperative 3<sup>rd</sup>, 6<sup>th</sup>, 12<sup>th</sup> month and late follow-up

### Postoperative pseudoarthrosis

The lack of substantial bone fusion 6 months following surgery is referred to as pseudoarthrosis. Cases with radiological pseudoarthrosis were recorded, which showed that pseudoarthrosis was detected radiologically in eight (13%) patients in the rigid group during the entire follow-up period. In the dynamic group, pseudoarthrosis was detected radiologically in five (8%) patients during the entire follow-up period [Table 5].

The comparison of pseudoarthrosis in the two groups showed  $P = 0.363$ . Therefore, there was no statistically significant difference between the two groups in terms of pseudoarthrosis ( $P > 0.05$ ). Considering the number of levels, pseudoarthrosis was the most common in patients in the rigid group, who had two levels of instrumentation (41%). However, this result did not provide evidence that an increase in the number of levels increased the risk of pseudoarthrosis.

### DISCUSSION

Lumbar stenosis typically occurs as a result of complex degenerative pathologies that compress the neural elements. Facet joint orientation and facet joint tropism are closely linked to disc degeneration in the lumbar spine.<sup>[5]</sup> Modic alterations and lipid infiltration in the multifidus and erector spinae muscles are also linked to disc degeneration.<sup>[6]</sup> The first step in the treatment is conservative in mild cases, but its benefit is limited because the symptoms are aggravated by movement. In advanced cases, the degenerative process exacerbates neural stenosis. Therefore, surgical methods are frequently

Table 4: The number and rates of cases related to the number of levels on adjacent segment disease

Number of instrumentation segments	Group 1 number of ASD	Group 2 number of ASD
1 segment	12/43 (28)	5/36 (14)
2 segments	5/17 (29)	2/16 (13)
3 segments	2/3 (67)	2/12 (17)
Total	19/63 (30)	9/64 (14)
Number of cases operated due to ASD	4 (6.3)	5 (7.8)

ASD: Adjacent segment disease

Table 5: Cases with radiological pseudoarthrosis

Number of instrumentation segments	Group 1 Number of screw pseudoarthrosis (%)	Group 2 Number of screw pseudoarthrosis (%)
1 segment	1/43 (2)	4/36 (11)
2 segments	6/17 (35)	0/16 (0)
3 segments	1/3 (33)	1/12 (8)
Total	8/63 (13)	5/64 (8)

used in treatment. Microsurgery and lumbar stabilization using rigid and dynamic systems are the basis of surgical treatment. In our study, we compared dynamic and rigid systems in terms of clinical, radiological, and surgical complications. While there was no difference between the two groups in terms of VAS and ODI scores, statistically significant differences were found in terms of ROM, fusion rates, and the development of ADS.

ASD is a potential long-term complication of spinal fusion. This condition includes several symptoms, such as disc degeneration, facet joint changes, and spinal stenosis. The reported incidence of symptomatic ADS has been defined as 5%–20% with varying follow-up times and different techniques. The etiology of ADS has not yet been fully defined. Two theories have been developed to explain this mechanism.<sup>[7]</sup> The first theory is focused on mechanical causes, such as the increased load exposure of the adjacent segment under stress and increased intradiscal pressure.<sup>[8]</sup> Cadaver studies have shown that the load on the instrumented segments after fusion was transferred to the adjacent segment, which increased the intradiscal pressure on the adjacent segment.<sup>[9,10]</sup> Moreover, the displacement of the rotation center in flexion and the formation of relative hypermobility comply with this theory.<sup>[11]</sup> The second theory emphasizes the natural progression of age-related degeneration without the involvement of a mechanism.<sup>[12]</sup>

Patient age and sex are risk factors for ASD. Aota *et al.* found that the risk increased in patients over 55 years.<sup>[13]</sup> Decreased proteoglycan and water content in elderly patients results in disc degeneration and causes the transfer of axial loading to the facet joint. Previous findings showed that ASD developed as a result of joint instability.<sup>[10]</sup> Previous reviews of the literature on ASD found that being over 55 years old is a major risk factor.<sup>[7,4]</sup> In Guigui *et al.*, the risk factors for ASD were defined as patient age, female gender, and use of a rigid instrument.<sup>[14]</sup>

In our study, while 26 of 28 patients with ASD were female, only two were male. The general female gender ratio, which was 78% in our study, was 93% in cases with ASD. Similarly, while the mean age in our study was 56.44, the mean age of patients who developed ASD was 60.32 years. In accordance with the literature, our results indicated that age and female gender were risk factors for ASD. However, no significant result was found to support that smoking, diabetes mellitus, and hypertension were risk factors for ASD.

Ghiselli *et al.*, in their case series of 123 patients, found that this rate was higher in patients who underwent long-segment fusion and lower in patients who underwent shorter fusion based on an average follow-up of 6 to 7 years.<sup>[15]</sup> Nagata

*et al.* found that the longer the instrumented segment, the shorter the amount of time required for ASD development and the higher the risk of ASD development.<sup>[16]</sup> Shono *et al.* reported that more rigid and longer-segment instrumentation increased the risk of ASD.<sup>[17]</sup> In Miyakoshi *et al.*, the results of single-segment instrumentation were more positive than those of previous studies in the literature.<sup>[18]</sup>

In our study, we found that adjacent segment degeneration developed in 21.5% of patients with single-segment instrumentation, 21.2% of patients with two segments, and 26.7% of patients with three segments, according to the fusion levels. Based on these results, it could not be concluded that the number of instrumentation levels is a risk factor for ASD.

In Park *et al.*'s review of 56 studies, the incidence of symptomatic ASD was defined as 5.2%–18.5% with varying follow-up times and different techniques.<sup>[7]</sup> Nakashima *et al.* conducted a retrospective study of 101 patients who were followed up for at least 10 years after fusion. Their findings showed that 80 cases had worsening lumbar spinal stenosis at the adjacent level and 87 cases had increased disc degeneration in the adjacent segment.<sup>[19]</sup> However, there have been fewer studies on ASD requiring revision surgery. Aiki *et al.* reported 7.7%<sup>[20]</sup> in their 2-year follow-up, and Gillet reported ASD requiring reoperation in 20% of patients in their minimum of 5-year follow-up.<sup>[21]</sup> In Guigui *et al.*, although 49% of ASD was observed radiologically, 8% became symptomatic and were reoperated.<sup>[14]</sup>

Kim *et al.* reported that fixation in the dynamic system, whether single or multilevel, caused less hypermobility in the adjacent segment and significantly reduced the risk of ASD.<sup>[22]</sup> Another study showed that the more rigid the instrumentation type used, the shorter the time required for patients to develop ASD.<sup>[23]</sup> Yang and Jiang's comparative study showed that the Dynesys dynamic system caused less ROM in the adjacent joint compared with the rigid system, and it preserved the disc structure in the adjacent segment, thus reducing ASD rates.<sup>[24]</sup> Thoracic kyphosis and pelvic tilt were found to be important indicators of overall rigidity and reference the ability of the spine to compensate for the sagittal plane deformity after spinal fusion.<sup>[25]</sup>

In our study, degeneration was found in the radiological adjacent segment in nine (14%) of 64 cases in which the dynamic system was used and in 19 (30%) of 63 cases in which the rigid system was used, according to instrumentation type. ASD became symptomatic in nine (7%) of all cases, and revision surgery was performed. Radiological and surgical ASD rates have been reported widely in the literature, which is consistent with the literature in our study.

In our study, we used PEEK rods as a dynamic system. Although they are not marketed as a dynamic stabilization device, PEEK rods have a softer profile than all other metal systems and therefore create a softer structure in the posterior lumbar spine. Compared with other dynamic systems, PEEK rod systems can reduce screw loosening by allowing the self-movement of the screw.<sup>[26]</sup> Because the PEEK modulus of elasticity is similar to bone, using this polymer as part of a pedicle screw–rod structure offers sufficient rigidity for fusion to occur, but it will not be exposed to the rigid stresses created by a titanium structure.<sup>[27,28]</sup> Biomechanical studies have shown that PEEK rods provide greater durability, strength, and general biomechanical profiles compared with metallic rod systems.<sup>[29]</sup> PEEK rods reduce the ROM of an unstable spinal segment with no significant difference in stability compared with titanium rods. The potential advantages of using PEEK rod systems for the spine are as follows: shares the load on the anterior column, which facilitates interbody fusion, reduces the stress between the bone and screw surface, reduces the rate of screw mobilization, and reduces the incidence of adjacent level disease in the long term.<sup>[30]</sup>

A potential disadvantage associated with the PEEK rod is the theoretical risk of pseudoarthrosis due to reduced hardness and rod breakage. Moreover, PEEK rods are difficult to follow in radiological imaging due to their radioactive properties. Inappropriate placement of spinal implants may complicate the perception of clinical results, and rod breaks may not be identified in postoperative imaging. However, radiopaque markers can be added to these rods to provide a radiographic evaluation of the position of the PEEK rods.<sup>[31]</sup> Some studies have reported good or excellent results with low complication rates in PEEK rod systems.<sup>[3,30,27,32]</sup> For rigid stabilization, to decrease pseudoarthrosis four-rod technique was recommended.

Whether a dynamic stabilization system maintains disc height is still controversial. Huang *et al.* analyzed 38 patients treated with the PEEK rod system and found that DHI increased slightly but gradually decreased below preoperative levels.<sup>[33]</sup> Their findings suggested that a pedicle-based dynamic system could not restore disc height. Kumar *et al.* compared disc lengths between dynamic and fusion levels and found that they decreased after surgery, but this change was not statistically significant at the 2-year follow-up.<sup>[34]</sup>

In our study, based on our findings from the literature review, our evaluations of the DHI and FH parameters showed that the DHI was significantly higher in the rigid group, but a decrease was observed in both groups during

the postoperative follow-up period. There was no difference between the preoperative and postoperative groups in either group. Regarding FH, the postoperative increase in the rigid group decreased to preoperative values in the following months, and a positive significant difference was observed between the preoperative and postoperative values in the dynamic group.

Wang *et al.* compared the K-Rod dynamic system and fusion in a 2-year follow-up of 98 patients. DHI and FH were increased in both groups compared with preoperative values, but there was no difference between the two groups. Similarly, although VAS and ODI values were significantly decreased in both groups compared with preoperative values, no statistically significant difference was observed between the two groups. Regarding segmental ROM and total ROM, the dynamic group was found to be significantly mobile in the fusion group. These results indicated that the dynamic system resulted in less restriction on physiological lumbar movements.<sup>[35]</sup>

Ogrenci *et al.* observed that in 172 patients who underwent PEEK rod instrumentation during an average 2-year follow-up, fusion rates were similar to those in which titanium rods were used according to the literature, but that ASD and other long-term complications were fewer than those in which titanium rods were used, and physiological lumbar movement was better maintained.<sup>[1]</sup> Ozer *et al.* also argued that in 71 patients who were operated on using various dynamic systems, less ASD was shown in follow-ups of at least 2 years compared with rigid systems; moreover, lumbar lordosis and disc height were maintained at a reasonable level.<sup>[2]</sup>

## CONCLUSION

In early experiences using PEEK rod systems, physiological spine movement, increasing fusion rates, minimal complications, reduction in adjacent segment degeneration, and biomechanical compatibility were demonstrated. Although further long-term studies are needed, and the cost of PEEK systems is likely to be a barrier, these results indicate the benefits of the use of PEEK rods in spinal surgery.

The clinical results of dynamic systems applied under appropriate conditions and with appropriate indications have shown similar efficacious results. Moreover, it has been observed that their advantages outweigh those of standard rigid systems with regard to long-term complications and physiological parameters. However, it is too early to make a final judgment regarding their usage, and longer follow-ups and larger case series studies are needed.

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**Conflicts of interest**

There are no conflicts of interest.

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