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Original article

Rod stiffness effect on adjacent segmental degeneration: a comparative long-term study

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Background: Adjacent segment disease (ASD) is a major complication following spinal instrumentation and fusion. The search for of the rod flexibility factors responsible for junctional degeneration is still ongoing.
Objective: Determine the rod stiffness and ASD following posterior instrumentation and fusion for lumbar spine and find the proper rod diameter for adult spinal instrumentation for fusion.
Subject and methods: Retrospective evaluation of all patients requiring spinal instrumentation to determine the different rod diameter that predispose toward junctional degeneration was completed. All patients requiring spinal instrumentation over a one-year period were studied retrospectively. One-hundred eight-seven patients (mean age 61.6 years) who had undergone decompression and fusion with pedicle screw instrumentation were evaluated. The average follow-up was 4.2 years. The average number of levels fused was 2.9 segments (range: 1-8). Adjacent spinal level pre- and post-operatively was determined on the plain X-rays. Junctional degeneration was defined as new episode of degeneration of the adjacent level on radiologic finding. Asymptomatic patients did not demonstrate junctional degeneration on the routine post-operative X-rays.
Results: ASD developed in 15 (8.0%) out of 187 patients, including compression fractures (n=2), spinal stenosis (n=6), and symptomatic disc collapse (n=7). There was a close correlation between the posterior instrument stiffness and the development of ASD (p=0.011). For fusion and fixation with 5.5 mm and 6.0 mm rod diameter, ASD occurred in four (3.7%) out of 108 patients and in 11 (13.9 %) out of 79 patients, resepectively. The incidences of ASD were greater when the posterior instrument used were stiffer in lumbar spine fusion. The pre-operative age, gender, and indication for surgery were not associated with the development of ASD.
Conclusion: The prevalence of symptomatic ASD relatively increased with increasing stiffness of spinal implant. The diameter of the longitudinal rod strongly affected the fixator loads, and influenced the stresses in the vertebral endplates. The rod diameter had influence on the stresses in the adjacent spinal motion segment.

Keywords: Adjacent degeneration, adjacent segment disease (ASD), posterior spinal instrumentation stiffness.

Adjacent segment disease (ASD) is a major complication following spinal instrumentation and fusion. The long-term effect of spinal fusion on adjacent motion segments is an increasing concern, especially with the use of rigid metal fixation. Symptoms may eventually develop at the proximal or the distal end of a fusion. They may be caused by disc degeneration, herniation, facet arthropathy, degenerative stenosis, segmental instability, spondylolithesis, or retrospondylolithesis at the adjacent unfused segment [1-7]. The biomechanical processes that promote this accelerated juxtafusion deterioration have been studied in vitro as well as in vivo [8].

Hsu and Zucherman [7] observed earlier juxtafusion breakdown in patients with rigid metal fixation compare with those with no fixation. Whether this quicker onset of breakdown is a result of implant rigidity or is caused by surgically induced or implant-induced facet degeneration remains to be established. Bony fusion alone may produce a segmental stiffness so much greater than that of a normal disc that the incremental stiffness from addition of metal fixation is relatively small [8].

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In a series of patients of a lumbar spine surgery, the correlation between rod diameter and adjacent degeneration has not been studied. Thus, it is important to determine the impact of having the right rod diameter in patients requiring spinal internal fixation.

In this study, we calculated the number of symptomatic adjacent degeneration encountered during a 10-year period. The effect of rod diameter on the rate of adjacent degeneration was evaluated.

Materials and methods

One-hundred eight-seven patients, who underwent pedicular screw & rod fixation and decompressive laminectomy for degenerative disease of lumbar spine, were retrospectively evaluated. All patients were operated on by the senior authors between October 1999 and June 2009. There were 129 females (69.0%) and 58 males (31.0%) with an average age of 61.6 years and range of 22 to 87 years. The levels of fixation spanned from the S1 through T10 and ranged from one to eight segments of fusion, with a mean of 2.9 segments instrumented.

The indications for surgery are included isthmic spondylolithesis, degenerative spondylolithesis, spinal canal stenosis, degenerative scoliosis, recurrent disc herniation, post discectomy degeneration, fracture, and corrective deformity.

Using X-ray image, we examined junctional degeneration. Using magnetic resonance imaging (MRI), we examined severe disc degeneration, facet joint arthritis, ligament, and capsule bulging with or without spinal canal compromise. We also determined adjacent degeneration, and described this manifestation based on previous literatures [6, 9].

All patients were evaluated with anterior-posterior (AP) and lateral radiographs on post-operative Day 1, at 3, 6, 12, 18, 24 months, and every year, or if symptomatic thereafter. The patients demonstrated junctional degeneration or instrumentation failure on the routine radiographs within the first 12 months. All 187 patients were included in the study, without any death or lost to follow-up in the first year. The minimum follow-up was 12 months and the maximum was 10 years, with a mean follow-up of 4.2 years. Patients were excluded from the study if they did not complete a minimum of 12 months of follow-up.

Table 1. Indications for surgery.

Indication	Number of patients
Degenerative spinal canal stenosis	130
Scoliosis	20
Degenerative spondylolithesis	22
Spondylolytic	2
Rupture disc with instability	6
Fracture	4
Correction deformity	2
Tumor	1

All patients underwent fixation with the same type of titanium pedicular screws with different of rods rigidity which were randomized used.

Table 2. Number of patients for 5.5 mm and 6.0 mm in rod diameter.

Spinal segment fixation	5.5 mm diameter (number)	6.0 mm diameter (number)
1 segment	23	20
2 segments	28	13
3 segments	27	19
4 segments	17	12
5 segments	5	8
6 segments	5	3
7 segments	1	4
8 segments	2	0

In symptomatic patients, lateral and flexion-extension X-rays were examined for radiographic evidence of adjacent level degeneration and instability. Adjacent stenosis was defined in terms of central canal diameter <10 mm [10, 11] by MRI. Junctional degeneration was defined as any of the above in a patient with symptoms attributable to the image finding.

For the statistical analysis, a Chi-square test was used with significance level of p = 0.05.

Results

Rod sizing and junctional degeneration

There appears to be a direct correlation between rod diameter and junctional degeneration (**Table 3**). Junctional degeneration was demonstrated in four out of 108 patients (3.7%) that underwent laminectomy and fixation with pedicular screw and rod diameter 5.5 mm. In other groups, laminectomy and fixation with pedicular screw and rod diameter 6.0 mm, 11 out of 79 patients (13.9%) presented with junctional degeneration.

Table 4 demonstrates that the percentage of patients who had junctional degeneration after fixation with larger rod diameter (6.0 mm) was greater than the percentage of patients who had junctional degeneration after fixation with smaller rod diameter (5.5 mm). Statistical analysis showed significant difference (p=0.011)

Number of instrumented levels and junctional degeneration

The number of instrumented levels ranged between one and eight levels with a mean of 2.9 levels. The average number of instrumented levels in the patients who suffered ASD was 3.4 *vs.* 2.8 for the entire group (p <47). Therefore, greater levels of fusion were associated with increased ASD. This tendency was similar to other studies. The numbers of levels fused did not correlate significantly with ASD. However, the small number of cases with five to eight levels of fusion might limit this analysis

Table 3. Number of fusion segment for 5.5 mm (**A**) and 6.0 mm rod diameter (**B**).

A) 5.5 mm diameter.

Number of fusion segment	Total (cases)	Adjacent segment disease (cases)
1	23	0
2	28	0
3	27	0
4	17	4
5	5	0
6	5	0
7	1	0
8	2	0
Total	108	4 (3.7%)

B) 6.0 mm diameter.

Number of fusion segment	Total (cases)	Adjacent segment disease (cases)
1	20	1
2	13	2
3	19	4
4	12	2
5	8	2
6	3	0
7	4	0
8	0	0
Total	79	11 (13.9%)

Table 4. Spine implant of junctional degeneration (cross-tabulation).

		Adjacent segment disease (ASD)		
		non-ASD	**ASD**	**Total**
Rod 5.5 mm	Count	104	4	108
	% within spine implant	96.3%	3.7%	100%
Rod 6.0 mm	Count	68	11	79
	% within spine implant	86.1%	13.9%	100%
Total	Count	172	15	187
	% within spine implant	92.0%	8.0%	100%

Chi-square test

	Value	**Difference**	**Asymptotic significance (two-sided)**	**Exact Significance (two-sided)**	**Exact Significance (one-sided)**
Pearson Chi-square	6.460*	1	0.011		
Number of valid cases	187				

*0 cells (0%) have count expected less than 5. The minimum count (expected) is 6.34. Chi-square = 6.46, Significance = 0.011 (<0.05).

Miscellaneous factors

Statistical analysis showed no significant difference with respect to number of fusion level, age, and gender among this group of patients (**Table 5**). Interestingly, there was no correlation between ASD and age group. It seems ASD mostly occurred at 60-69 years old.

Table 5. Age range of junctional degeneration (cross tabulation).

			Adjacent segment disease (ASD)		
			non-ASD	**ASD**	**Total**
Age range	50-59	Count	62	4	66
		% within age range	93.9%	6.1%	100%
	60-69	Count	64	8	72
		% within age range	88.9%	11.1%	100%
	70-79	Count	46	3	49
		% within age range	93.9%	6.1%	100%
	Total	Count	172	15	187
		% within age range	92.0%	8.0%	100%

Chi-square tests

	Value	**df**	**Asymp. Sig. (two-sided)**
Pearson-Chi square	1.515[a]	2	0.469
Likelihood ratio	1.472	2	0.479
Linear-by-linear association	0.016	1	0.900
Numbe of valid cases	187		

[a]one cell (16.7%) has count expected less than 5. The minimum count (expected) is 3.93.

Discussion

To decrease the incidence of junctional degeneration, we have to identify material factors predisposing patients toward it. This includes factors of rod stiffness to predispose toward junctional degeneration. In the present study, we retrospectively evaluated all patients requiring internal fixation devices for treatment of spinal disorders.

Elasticity of rod materials

Mechanical properties of the bridged region may be altered by stabilizing a lumbar spine with an implant. Transforming from non-mobile to mobile fusion part may create bending force to the junctional area. More rigid and long lever arm of fusion segment may give more stress to increase the moment torque, which accelerates junctional instability and degeneration [12]. Strength of fusion segment depends on vertebral body, intervertebral disc, bone fusion mass, and pedicular screw-rod system [13, 14]. Rod stiffness depends on diameter as the moment of inertia increases by rod's radius. Accordingly, the diameter of the longitudinal rod may affect the fixator loads, and influence the stresses in the vertebral endplates. Since the stresses in the bridged discs are produced, the internal fixator may influence the stresses in the anulus fibrosus and the pressure in the nucleus pulposus of the adjacent discs [12].

In general, an extreme strain is induced on the junctional spinal level between very rigid fusion levels and mobile intact levels as a result of stress from differentiation [15-17]. Larger degenerative changes are associated with developing a neurological deficit or pain [18]. When weight is applied to an already-degenerative spine, it may lead to progression of the deformity [19].

It is possible to assume that excess strain, caused by a more rigid rod fixation crossing from a mobile to immobile spinal segment, would predispose toward junctional degeneration. In the present study, there were 79 cases where oversize, and stiffer instruments were used. Out of these cases, 13.9% experienced junctional degeneration. Interestingly, the group that used with less-stiff rod had a failure rate was 3.7%. This difference was statistically significant. In addition, a subgroup analysis of age and gender did not yield any statistically significant differences. Both these results are in concordance with the current literature.

All patients had plain X-rays every six months post-operatively as routine. Therefore, we evaluated only symptomatic patients using films thereafter. Although there may have been patients with asymptomatic instrumentation failure within one- to two-year follow-up period, it was not clinically significant at this time. A more substantial follow-up period may yield different results.

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