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ORIGINAL ARTICLE

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Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion

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Abstract Adjacent segment degeneration following lumbar spine fusion remains a widely acknowledged problem, but there is insufficient knowledge regarding the factors that contribute to its occurrence. The aim of this study is to analyse the relationship between abnormal sagittal plane configuration of the lumbar spine and the development of adjacent segment degeneration. Eighty-three consecutive patients who underwent lumbar fusion for degenerative disc disease were reviewed retrospectively. Patients with spondylolytic spondylolisthesis and degenerative scoliosis were not included in this study. Mean follow-up period was 5 years. Results were analysed to determine the association between abnormal sagittal configuration and post operative adjacent segment degeneration. Thirty-one out of 83 patients (36.1%) showed radiographic evidence of adjacent segment degeneration. Patients with normal C7 plumb line and normal sacral inclination in the immediate post operative radiographs had the lowest incidence of adjacent level change compared with patients who had abnormality in one or both of these parameters. The difference was statistically significant ($P<0.02$). There was no statistically significant difference in the incidence of adjacent level degeneration between male and female patients; between posterior fusion alone and combined posterolateral and posterior interbody fusions; and between fusions extending down to the sacrum and fusions stopping short of the sacrum. It was concluded was that normality of sacral inclination is an important parameter for minimizing the incidence of adjacent level degeneration. Retrolisthesis was the most common type of adjacent segment change. Patients with post operative sagittal plane abnormalities should preferably be followed-up for at least 5 years to detect adjacent level changes.

Keywords Lumbar fusion · Adjacent segment · Sagittal alignment

Introduction

Adjacent segment degeneration (ASD) has been reported by many authors following lumbar and lumbosacral fusions [1,5,7,9,13,19,21,23,24,26,30,31,32]. In this study the term ASD is used to refer to the onset of degenerative changes in the previously normal disc spaces adjacent to the fusion segment. This becomes symptomatic in many cases and may need re-operation. It is well known that re-operations following lumbar fusions do not always carry good results and that the percentage of good results decreases with each revision surgery [4,11,16]. It is therefore essential to minimize the possibility of re-operation as much as possible. The reasons for adjacent segment degeneration are not fully understood as yet, although various causes have been speculated. The aim of this study is to examine the association of sagittal plane alterations with ASD.

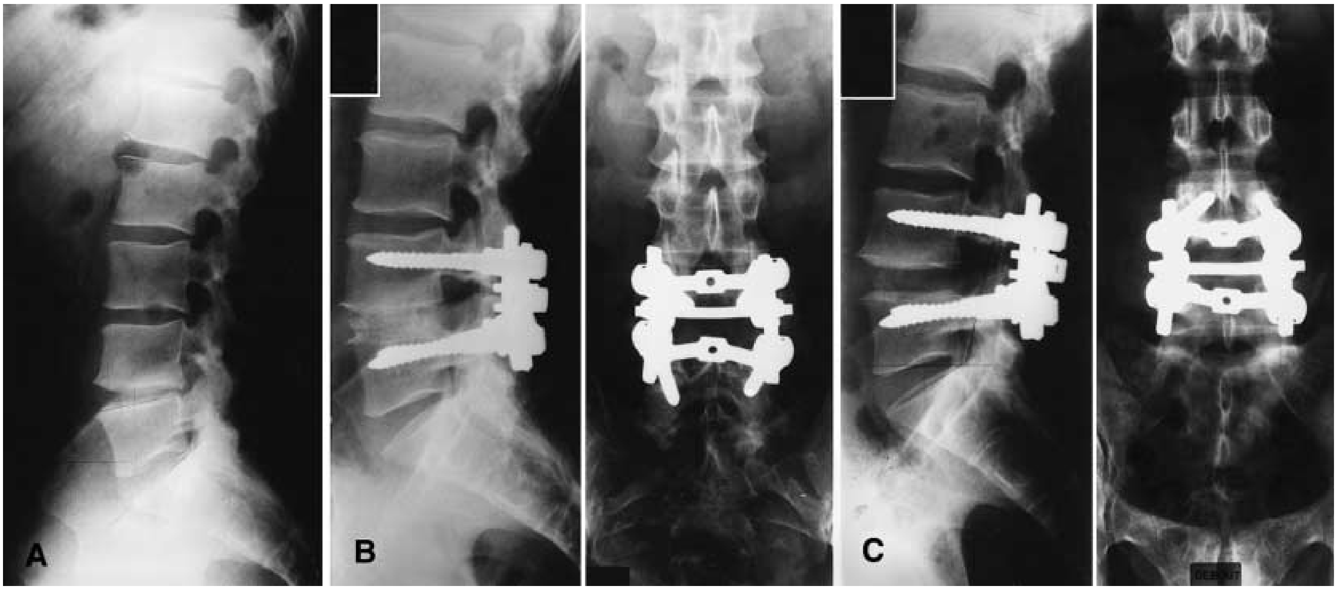
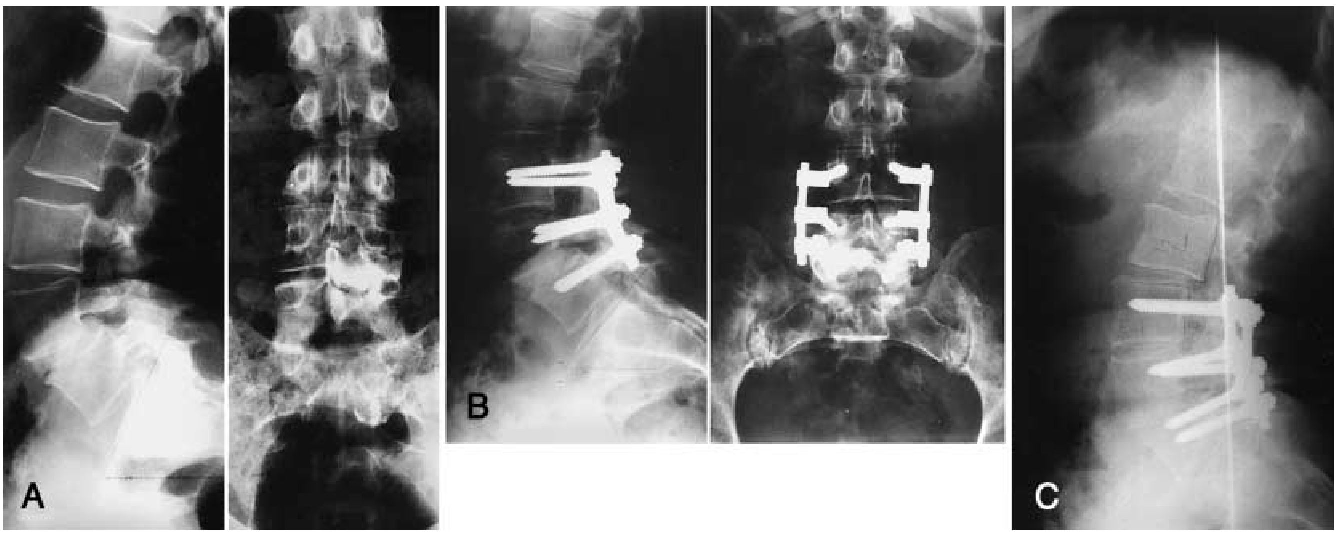


Fig. 1 **A** This patient had lumbar lordosis of 18° and sacral inclination of 40° with antepulsion of plumb line pre operatively. **B** Immediate post operative radiographs showed improvement in lordosis to 34° and normalisation of plumb line. Sacral inclination had reduced to 30°. **C** Symptomatic retrolisthesis developed at the level above 6 years later

Patients and methods

Eighty-three patients underwent lower lumbar or lumbosacral fusion for degenerative disc disease (degenerative spondylolisthesis, spinal stenosis, back pain due to disc degeneration not responding to prolonged conservative management). Patients with lumbosacral fusions for spondylolytic spondylolisthesis as well as degenerative scoliosis were not included in this study. All patients had posterolateral fusion with pedicle screw and rod instrumentation (Sofomor-Danek, Colorado, USA) and autogenous bone grafting. In 30 patients, posterior lumbar interbody fusion (PLIF) using carbon cages (Nexis, Sofomor-Danek) filled with autograft was combined with posterolateral fusion at the time of initial surgery. The PLIF was used to enhance the solidity of fusion in patients thought to be at higher risk for pseudarthrosis, wide open disc space at the level of olisthesis, sagittal orientation of facet joints and significant mobility on the preoperative flexion/extension lateral radiographs of the lumbar spine [28]. The mean follow-up period was 5 years and the minimum follow-up was 2 years (range 2–12 years). The mean age of the patients at follow-up was 56.6 years (range 34–88 years). There were 45 females and 38 males.

Fig. 2 **A** Isolated measurements of lumbar lordosis are not useful in assessing overall sagittal balance. This patient had antepulsed plumb line even with a lordosis of 75°. **B** Immediate post operative radiographs showing ‘good’ lordosis of 65° and normal sacral inclination of 50° but with persistent antepulsion of plumb line. The lordosis and the sacral inclination were not ‘good enough’ to provide a balanced plumb line. **C** Development of retrolisthesis 5 years after spinal fusion



Forty-eight patients had fusion down to the sacrum and 35 had fusion stopping short of the sacrum (down to L4 or L5). The normal status of the discs at the adjacent levels prior to the operation had been ascertained using plain radiographs and MRI scans that had been obtained for all patients. Discography had been used to assess the discs below the fusion in cases of fusion stopping at L4 or L5. The fusion was not extended to the sacrum in cases with disc degeneration limited to one or two discs above the L5-S1 disc, provided the L5-S1 disc was normal on discography. The full-length sagittal radiographs of the spine were assessed by three independent observers to detect any change post operatively. The following parameters were measured on the pre- and postoperative radiographs:C7 sagittal plumb line, lumbar lordosis (L1-S1), lordosis above the level of fusion, and sacral inclination. Patients were divided into four groups based on the location of C7 plumb line and the sacral inclination on the immediate post operative radiographs:

A. Normal plumb line and normal sacral inclination (25 patients)
B. Normal plumb line and vertical sacrum (23 patients) (Fig. 1)
C. Antepulsed plumb line and normal sacral inclination (18 patients) (Fig. 2)
D. Antepulsed plumb line and vertical sacrum (17 patients)

The normal plumb line was defined as a C7 sagittal plumb line falling within 2.5 cm of the posterosuperior corner of S1 vertebra [17]. Normal sacral inclination was defined as a sacral inclination between 40°and 53° [16]. A sacral inclination of equal to or less than 35° was termed as a vertical sacrum. The normative data studies for sacral inclination have identified 40° as the lower limit of sacral inclination. In this study, 35° was taken as the cut-off point to identify a vertical sacrum to minimize the intrinsic errors of the Cobb measurement. A measurement at least 5° below the lower limit of normal was accepted as a vertical sacrum.

For statistical analysis the chi-square test was used to assess the difference between proportions and paired *t*-test was used for comparison of pre and post operative measurements. Statistical analysis was done using Stat View SE (Abacus Concepts, Inc., Berkeley, Calif.). Statistical significance was set at the $P<0.05$ level.

Results

Of the 83 patients, there were 31 patients with radiographic evidence of adjacent level degenerative changes above the level of fusion (36.1%). Of the 31 patients with changes of ASD, 14 had required a second surgical intervention (16.8%). Adjacent segment degeneration was manifest as anterolisthesis of the vertebra above the fusion in six patients, as retrolisthesis of the vertebra above the fusion in 15 patients, stenosis (myelographic study) at the disc space above without vertebral olisthesis in four patients and as isolated disc space narrowing in six patients. Degenerative changes below the level of fusion (with L4 and L5 fusions) were seen in two out of 35 patients (5.7%).

There were 21 females and ten males with changes of ASD. This means that 46.7% of females and 26.3% of males had adjacent level changes. There were 16 cases of ASD in fusions down to the sacrum (33.3%) and 15 cases of ASD in fusions stopping short of sacrum (42.8%). There were 11 cases of ASD in patients who had PLIF with posterolateral fusion (30%) and 20 cases in patients who had posterolateral fusion alone (37.7%). None of the above differences were statistically significant.

The mean age of patients with changes of ASD was 59 years and the mean age of patients without changes of ASD was 55.4 years. The changes manifested after a mean 5.2 years following initial surgery. When patients with ASD changes were stratified according to the duration of follow-up, there were two patients with ASD in the 2-year follow-up group, five patients in the 3-year follow-up group, six patients in the 4-year follow-up group and 18 patients in the more than 5 -year follow-up group. This means that over 75% of cases of ASD manifested after 4 years of follow-up.

In group A (normal plumb line and normal sacral inclination) two out of 25 (8%) patients had ASD changes. In group B (normal plumb line with vertical sacrum), 11 out of 23 patients (47.8%) had ASD. In group C patients (antepulsed plumb line with normal sacral inclination) nine out of 18 patients (50%) had ASD and in group D (antepulsed plumb line with vertical sacral inclination) nine out of 17 patients (53%) had ASD. The difference between results in group A and the other three groups (B,C,D) was statistically significant ($P<0.02$). There was no statistically significant difference between groups B, C and D compared against each other.

The mean preoperative and postoperative lordosis and sacral inclinations of groups A to D is shown in Table 1. In group C, nine out of 18 (50%) patients had antepulsion of plumb line preoperatively and in group D, 12 out of 17 (70.5%) had antepulsion of plumb line preoperatively.

Of the 31 patients with ASD two patients had fusion at three levels of the lumbar spine 6.5%), 13 patients had fusion at two levels (42%) and 16 patients had fusion at one level (51.6%). Of the 52 patients with no ASD, one patient had four level fusion (2%), five patients had three level fusion (9.5%), 22 patients had two level fusion (42.3%) and 24 patients had one level fusion (46.2%). On the whole, 16 out of 40 patients (40%) with one level fusion had ASD while 15 out of 43 (34.8%) patients with more than one level fusion had ASD.

Table 1 Mean values for lumbar lordosis and sacral inclination

Group	Description	Lumbar lordosis		Sacral inclination	
		Pre-op	Post-op	Pre-op	Post-op
A	Normal plumb line, normal sacral inclination	42.2°	44.6°	44.1°	42.6°
B	Normal plumb line, vertical sacrum	29.2°	32.6°	27.9°	28.0°
C	Antepulsed plumb line, normal sacral inclination	49.4°	46.2°	51.5°	50.0°
D	Antepulsed plumb line, vertical sacrum	33.4°	33.4°	33.7°	32.0°

Discussion

The occurrence of degenerative changes above the level of fusion has been reported for many years. Long-term follow-up studies of noninstrumented posterior lumbar fusions seem to suggest a relatively high incidence of radiographic degenerative changes without significant clinical effects [7,13,22]. However, more recent studies have shown that a significant number of patients with ASD often need re-operation in view of their symptoms [5,25,27,31]. It is known that re-operations following spinal fusion do not always carry a good prognosis and the success rate seems to decrease with each successive surgical intervention [4,11,16]. Hence, it is appropriate to study the factors that may cause an increased incidence of ASD. Biomechanical and clinical studies have shown increased mobility as well as increased intradiscal pressures at motion segments above, following spinal fusion [10,15].

Factors that have been cited as contributing to ASD include advanced patient age, female sex, and the use of rigid instrumentation. Guigui et al. [9] showed that ASD was significantly more common in patients treated earlier for degenerate disc disease than in younger patients with spondylolisthesis. ASD was seen in 49% of radiographs in their study but only around 8% required surgery. In our study 36.1% of patients had ASD and 16.8% required re-operation. The difference is probably because all the patients in our study had degenerate disc disease and there were no patients with spondylolisthesis. Our re-operation rate is similar to Etebar and Cahill's (14.4%) [5]. As found by Aota et al. [1], retrolisthesis was the most frequent type of ASD in our study. Furthermore in both studies, the incidence of ASD above the level of the fusion was much higher (36.1%) than the incidence of ASD below the level of the fusion segments (5.7%).

Adjacent segment degeneration has been reported to be more common in females [5]. In our study this trend was seen, too, but was not statistically significant. Pedicle screw instrumentation has been cited as a possible contributory factor for ASD [5,25,32]. We are unable to confirm this in our study as there was no statistically significant difference in the incidence of ASD between instrumented and non-instrumented fusions. In our study there was no significant difference in the mean ages of patients with and without ASD (59 years vs. 55.4 years).

Interbody fusion was said to be an underlying cause for ASD by Rahm and Hall [25]. In our study there was no statistically significant difference in the incidence of ASD between patients who had posterolateral fusion alone and those who had both posterolateral and posterior interbody fusion. The effects of the length of the fusion on the monosegmental motion of the lumbar spine has been discussed by Kettler et al. [18]. In the present study, there was no evidence of increased incidence of ASD with longer segment fusions. On the contrary, there was a nearly 5% higher incidence of ASD in patients with single level fusions compared with multiple level fusions, but this difference was not statistically significant. In our study, ASD developed after a mean of 5.2 years following spinal fusion. This is in contrast to the report of Wiltse et al. [32] that pedicle screws do not increase the incidence or severity of transition zone change in the first 7 years after surgery.

There are very few studies on the role of alteration of sagittal plane anatomy in contributing to ASD [19,27]. Lazennec et al. [18] showed a statistically significant correlation between reduction of sacral inclination and back pain following lumbosacral fusion. They also showed that sacral tilt decreased from the immediate post operative period to the time of last follow-up.

In the present study, the lowest incidence of ASD was seen in patients with normal C7 sagittal plumb line and normal sacral inclination (8%).The difference between this group and the other three groups with abnormality in either the plumb line or the sacral inclination or both was statistically significant. This means that patients with a normal plumb line and a normal sacral inclination postoperatively have a much lower probability of developing ASD than patients with abnormality in one or both of them.

In our study, 50% of patients with antepulsion of plumb line and normal sacral inclination had changes of ASD. When the plumb line is antepulsed, it means that pelvic compensation either did not occur (e.g. hip arthritis) or was insufficient to correct the grossly abnormal amount of antepulsion. The instantaneous axis of rotation (IAR) of a structurally normal spine passes through the anterior third of lumbar disc spaces and the moment arm of the centre of mass is balanced by the moment arm of the spinal muscles [12]. With antepulsion, the moment arm of the center of mass increases and causes increased loading of the unfused motion segments. Another reason for disc degeneration with antepulsion is probably the extensor muscle activity during attempts to maintain balance [29]. Compressive loading of the discs is highest with trunk extension exercises [2].

In patients with antepulsion with vertical sacrum, the incidence of ASD was even higher (53%). This is not surprising because these patients have no further pelvic compensation remaining at all.

In patients with normal C7 sagittal plumb line and vertical sacrum, the incidence of ASD in the present study was quite high (47.8%). This may appear to be a surprising finding at the outset but biomechanical explanation for this can be quite easily found. The results of group B in Table 1 show that these patients had low lumbar lordosis balanced by a low sacral inclination preoperatively and continued to be the same postoperatively. A mean sacral inclination of 28° means that the hips are in relative extension to begin with. Any 'extension thrust' to the trunk would have to be accommodated by the lumbar spine. The lower lumbar spine is fused surgically and, hence, the available motion segments above the fusion will be subject to more deformation and possibly ASD. Jackson and McManus [17] have shown that adults with back pain (without any fusion) tend to have less distal lumbar lordosis and vertical sacrum than people without back pain. Addition of spinal fusion to these patients simply eliminates mobility of the distal segments and transfers the stresses proximally.

A reduction in lumbar lordosis can be, to a certain extent, compensated by a similar reduction in sacral inclination to keep the C7 plumb line within normal limits [30]. Reduction in sacral inclination is an indicator of the amount of extension of the pelvis (hip joint), where the compensation is occurring [14]. Legaye et al. [21] have emphasized the importance of 'pelvic incidence' in relation to the sagittal balance of the spine. Hip extension decreases with age and with osteoarthritis of the hip [26]. A patient with degenerate disc disease may or may not have the 'extension reserve' in the hips to accommodate loss of lordosis.

Conclusions

In the present study the only statistically significant difference between patients with ASD and those without ASD following lumbosacral fusion for degenerate disc disease was the presence of a normal C7 sagittal plumb line with a normal sacral inclination in the patient group with a low incidence of adjacent level degeneration. The incidence of adjacent segment degeneration was high even with a normal plumb line when the sacrum was vertical. Normality of sacral inclination seems to be an important component of sagittal alignment in patients with fused lower lumbar segments. It is probably important to follow up patients with sagittal plane abnormalities for at least 5 years before discharging them from the clinic.

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