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ORIGINAL ARTICLE

Disc height reduction in adjacent segments and clinical outcome 10 years after lumbar 360° fusion

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Abstract Adjacent segment degeneration (ASD) is discussed to impair long-term outcome after lumbar interbody fusion. Nevertheless the amount and origin of degeneration and its clinical relevance remain unclear. Only little data is published studying quantitative disc height reduction (DHR) as indicator for ASD in long-term follow-up. Forty patients (23 men, 17 women) (group 1: degenerative disc disease, $n = 27$; group 2: lytic spondylolisthesis, $n = 13$) underwent lumbar 360° instrumentation and fusion between 1991 and 1997. Preoperative and follow-up lateral lumbar radiographs were studied. Disc heights of first and second cephalad adjacent segments were measured by Farfan's technique and Hurxthal's technique modified by Pope. Clinical outcome was studied using Oswestry disability index (ODI) and visual analogue scale (VAS). Age, gender, prior surgery, fusion rate and number of fusion levels were investigated as potential factors affecting the outcome. Mean follow-up was 114 (72–161) months. Clinical outcome showed an improvement of 44.6% in ODI and 43.8% in VAS with a tendency towards better results in group 2. Fusion rate was 95%. Disc height of the first cephalad adjacent segment in all patients was reduced by on average 21% (Farfan, $P < 0.001$) and 19% (Pope, $P < 0.001$), respectively, and that of the second adjacent level by on average 16% (Farfan, $P < 0.001$) and 14% (Pope, $P < 0.001$), respectively. A tendency towards more disc height reduction (DHR) in the degenerative group was observed. Advanced age correlated with advanced DHR ($P \leq 0.003$, $r = 0.5$). Multiple level fusion led to a more pronounced DHR than 1-level fusion ($P = 0.028$). There was a tendency towards more DHR in the first adjacent disc compared to the second. Gender, prior surgery of the fused segment and fusion level did not affect the amount of DHR. There was no correlation between the clinical outcome and DHR. Lumbar fusion is associated with DHR of adjacent discs. This may be induced by additional biomechanical stress, ongoing degeneration affecting the lumbar spine and advancing age. However, clinical outcome is not correlated with adjacent DHR.

Keywords Adjacent segment · Lumbar fusion · Disc height · Clinical outcome · Disc degeneration

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Introduction

Lumbar fusion is a common procedure in spine surgery [16]. Indications comprise degenerative disorders and lytic spondylolistheses [16, 18].

During the last years lumbar fusion has been increasingly criticized [2]. Studies have shown that clinical results in long-term follow-up (FU) are similar to those of conservatively treated patients [3, 7]. Side effects of lumbar fusion are discussed: ASD, pseudarthrosis, bone graft morbidity, high rates of re-operation, implant failure and sagittal spinal imbalancing. They have brought up alternative technologies like disc arthroplasty [9].

ASD following fusion has been subject of several studies [11, 17, 27]. It is of major clinical interest as it is one of the main arguments pointed out by the supporters of arthroplasty to develop motion-retaining devices instead of rigid fusions. The question whether it is a consequence of fusion or part of natural degeneration is not yet answered [17].

Adjacent segments have been studied using different techniques [radiography, computed tomography (CT), magnetic resonance imaging (MRI)] [6, 20, 29, 38]. Disc height has been described as indicator of disc degeneration and regeneration [26, 31]. Correlation of ASD and clinical outcome is still unclear [26].

Only few studies systematically investigated disc height of adjacent segments in long-term FU. The aim of the present study was to examine the disc height of the two cranial adjacent segments before surgery and at long-term FU and to determine the influence on clinical outcome.

Materials and methods

Sixty-five consecutive patients had posterior–anterior lumbar 360° fusion between November 1991 and December 1997. Indications were low back pain due to degenerative disc disease (DDD) or lytic spondylolisthesis I° or II°, that had failed conservative treatment for at least 6 months. Charts and radiographs of all patients were examined. Patients with a complete set of data and no additional surgery of the fused or adjacent segment during FU were invited for examination.

Forty patients (23 men, 17 women) were included, 25 were dropouts because of the impossibility to contact them (9), non-compliance (7), incomplete data (5), additional lumbar surgery during FU (3) and deceased (1).

Mean age at surgery was 41.0 years [standard deviation (SD) 11.9 years]. In 27 patients (16 men, 11 women) indication for surgery was DDD (group 1), mean age at surgery was 45.1 years (range 26–66 years). In 13 patients (7 men, 6 women) indication was lytic spondylolisthesis (group 2), mean age at surgery was 32.6 years (range 11–47 years). The numbers of fused levels in both groups are compiled in Table 1.

Thirteen patients (48%) in group 1 had surgery (non-fusion surgery because of disc herniation) of the fused segment(s) before fusion, no patients in group 2.

Table 1 Numbers of fused levels

Fused levels	Group 1	Group 2
L5–S1	9	9
L4–S1	11	1
L3–S1	4	1
L1–L5	1	0
L3/4	1	0
L4/5	1	2

In group 1 fusion length averaged 1.8 segments (range 1–4; SD 0.8) and in group 2 it was 1.2 segments (range 1–3; SD 0.6)

Surgery was performed in a uniform technique in all patients by two surgeons. Pedicle screws and rods were used posteriorly. Fusion was achieved by laminar decortication and arthrodesis of the facet joints. In case of lytic spondylolisthesis decompression of the affected nerve roots was performed by resection of the mobile posterior arch followed by posterolateral fusion. Autogenous bone graft from the posterior iliac crest was used. Anterior surgery was performed via retroperitoneal approach using titanium cages filled with autogenous bone graft.

Operation time averaged 269 min (range 150–390 min). Mean blood loss was 1,120 ml (range 300–2,700 ml). Complications included single rod breakage in one patient, loosening of a rod from the screw head was observed in a second patient, however, without pseudarthrosis in both cases. In both cases no clinical complaints were present correlating to these findings, so no additional surgery was performed. Two patients had delayed superficial wound healing at the anterior approach requiring superficial revision surgery. Three patients had transient postoperative pareses probably resulting from intraoperative nerve root retraction during decompression. Two patients developed transient retrograde ejaculation (possibly a result of the use of electrocautery during the anterior approach to the lumbosacral junction) that had recovered at FU.

Mean FU was 114 months (SD 17.9 months). Prior to surgery and at FU, patients had an orthopaedic and neurologic examination as well as standing radiographs. Clinical outcome was rated using VAS and ODI [24, 25]. Before surgery either CT or MRI was performed. Discography was applied additionally on an individual basis in 24 patients presenting discs with mild signs of degeneration in MRI or CT above or below the main pathologic disc. Radiographic evaluation contained a standard anterior–posterior and lateral view of the lumbar spine, centered on L3 (Multix-Top, Siemens Medical Solutions, Forchheim, Germany).

The status of fusion was evaluated four times by two specialists in an established technique [14]. Criteria for fusion were bony bridging, bony continuity between endplates, trabecular structure in anterior bone bridge and lack of radiolucent lines around implants. Fusion rate was classified as "fused (3)" (3 criteria positive), "probably fused (2)" (2 criteria positive), "probably not fused (1)" (1 criterion positive) and "pseudarthrosis (0)" (evidence of radiolucent lines). The degree of agreement between the four readings was ascertained by calculating Kendall-*W*-coefficients.

Disc heights of the two cranial adjacent segments (in relation to the upper fusion end) were measured using the techniques of Farfan and Pope (*R*1) in lateral standing radiographs [6, 29]. Also in floating fusions (lumbar fusion with at least one intact caudal adjacent disc), only the two cranial adjacent segments were studied as it is known, that in floating fusions ASD is more common in the cranial segments than in the one below [37]. Measurements were performed three times in each patient by two investigators at 3 days. One reader performed two measurements, allowing calculation of intraobserver reliability. The results of the second reader were compared with the mean result of both measurements of the first, so interobserver reliability could be ascertained.

Statistics was performed by a statistician using SPSS 11.1.1. Before testing statistically, each continuous variable was analyzed exploratively about its normal distribution ("Kolmogorov–Smirnow test"). Categorical variables are expressed as frequency and percentage, continuous variables as mean, range and SD. Differences were considered significant at $P < 0.05$. Wilcoxon and Mann–Whitney *U* test were applied, as well as Pearson's correlation coefficient "*r*".

Results

Clinical results

Improvement was significant in both groups using ODI and VAS ($P \leq 0.004$) (Table 2). Mean improvement in all patients ($n = 40$) was 44.6% in ODI (range –89 to 100%) and 43.8% in VAS (range –14 to 100%). In group 1 improvement of ODI averaged 41.1% (range –33 to 100%) and that of VAS 38.5% (range –14 to 100%). In group 2 mean improvement of ODI was 51.7% (range –89 to 100%), that of VAS 55.0% (range 0–100%).

Statistics did not show any significant difference between improvements in both the diagnosis groups, between patients with one- and multiple-level fusion or between patients with or without prior surgery. Gender and age did not show a significant correlation to clinical improvement.

Table 2 Clinical results using ODI and VAS before surgery and at FU

Group	Time	ODI mean (SD)	VAS mean (SD)
1 + 2	Before surgery	56.6 (18.8)	8.6 (1.3)
1 + 2	At FU	30.8 (20.6)	4.9 (3.0)
1	Before surgery	57.8 (19.6)	8.5 (1.3)
1	At FU	34.8 (20.6)	5.4 (2.9)
2	Before surgery	54.4 (18)	8.8 (1.1)
2	At FU	22.6 (18.8)	3.9 (2.9)

Fusion rates

Mean fusion rate was 2.8 (SD 0.5) in group 1 and 2.6 (SD 0.6) in group 2. The degree of agreement between the four measurements showed Kendall-*W*-coefficients between 0.73 and 0.85. Only 2 out of 40 patients were "probably not fused". This is equivalent to an overall fusion rate of 95%. There was no significant difference in fusion rate between groups 1 and 2. Fusion rate did not correlate with ODI or VAS, or with age or duration of FU.

Disc height

1. *Intra- and interobserver errors*: disc height measurements indicated a mean intraobserver error of 1.62% (SD 1.40%) for Farfan's method and 3.15% (SD 2.79%) for Pope's method. Mean interobserver error was 1.70% (SD 1.39%) for Farfan's method and 4.33% (3.83%) for Pope's method.
2. *Overall DHR*: Table 3 shows the DHR of the first and second adjacent disc in percentage. In both the techniques, DHR was highly significant for both the studied discs ($P < 0.001$).
3. *Diagnosis groups*: comparing both diagnosis groups, a significant difference in DHR was not found, but a clear tendency towards a more explicit DHR in the degenerative group was found.

Table 3 DHR of the first and second disc adjacent to fusion in percentage

Group	Technique	First disc mean (SD) (%)	Second disc mean (SD) (%)
1 + 2	Farfan	21.0 (23.3)	15.9 (16.0)
1 + 2	Pope	18.9 (24.4)	13.8 (16.3)
1	Farfan	25.2 (26.8)	18.6 (17.4)
	Pope	22.7 (28.1)	14.0 (17.9)
2	Farfan	12.2 (7.5)	10.5 (11.5)
	Pope	10.9 (11.0)	13.3 (12.9)

4. *Age*: the degree of DHR of first and second adjacent disc due to Farfan in all patients correlated with age (first disc: $P = 0.002$, $r = 0.5$; second disc: $P = 0.003$, $r = 0.5$), meaning increased age correlated with increased DHR. In group 1, age significantly correlated with DHR of the first and second adjacent disc due to Farfan (each $P = 0.004$, $r = 0.5$). In the younger group 2, there was no correlation between age and DHR.
5. *First versus second adjacent disc*: the degree of DHR of the first adjacent disc in all patients significantly correlated with the degree of DHR of the second disc (Farfan: $P = 0.005$, $r = 0.4$; Pope: $P = 0.012$, $r = 0.4$) showing no significant difference. Nevertheless statistics showed a trend towards a more pronounced DHR of the first adjacent disc compared to the second. In group 1, DHR of both discs significantly correlated with each other (Farfan: $P = 0.012$, $r = 0.5$; Pope: $P = 0.043$, $r = 0.4$) without any significant difference. In group 2 there was also no significant difference between both the discs.
6. *Single versus multiple level fusion*: all patients considered there was a significant difference in DHR of the first adjacent disc due to Farfan between patients with single (12.7% DHR) and multiple-level fusion (31.1% DHR) ($P = 0.028$).
7. *Clinical results*: VAS and ODI did not correlate with DHR.
8. *Others*: gender, fusion rate, prior surgery and duration of FU did not significantly affect DHR. Comparing DHR of L2/3, L3/4 and L4/5, no significant difference could be found but a tendency towards less height reduction in L2/3 was found. Statistical analysis, comparing DHR of patients with floating fusion and those without floating fusion, showed no statistical difference and not even a tendency in DHR between both the groups, neither for the first nor for the second disc.

Discussion

Clinical results

Clinical results correspond well to the literature [3]. There was a tendency towards better improvement in lytic spondylolisthesis compared to DDD [14]. A reason could be that DDD patients present more risk factors for ASD (higher age and fusion length and probably more degeneration in adjacent segments as part of the underlying DDD) [27]. Literature does not clearly answer the question whether DDD is rather a local monosegmental than a systemic multisegmental pathology implying that patients often have several degenerated segments in different stages of degeneration. It could be hypothesized that only the most degenerated segments lead to surgery. Segments not included in fusion may still contribute to the clinical outcome.

In the literature there is no impact of age, gender, prior surgery and fusion length on clinical outcome, corresponding to our results [34]. Blood loss and operation time are consistent with the literature [8].

Fusion rates

Our Kendall-*W*-coefficients showed a high degree of agreement assessing fusion rates. Only two patients showed a “probably not-fused” situation, one with a good and one with an insufficient clinical result. The latter refused further treatment. Our fusion rate of 95% did not depend on diagnosis, gender or prior surgery and did not correlate with age, length of FU or clinical outcome, corresponding to the literature [2, 12, 14].

Disc height

ASD following fusion is of major concern. The reported incidence ranges from 8 to 100% [26, 28]. Clinically symptomatic ASD is reported only in 5.2–18.5% [19, 22]. Insertion of pedicle screws into the upper vertebra to be fused sometimes necessitates distal resection of the upper facet capsula or joint. This factor has been described to promote ASD, as does the accidental damage of the facet joints [5].

Intra- and interobserver errors

To maximize reliability of DHR measurements, the most accurate applicable techniques were chosen and additionally two independent readers performed three measurements. We found very low intra- and interobserver errors. So reliability of the measurements is sufficiently proven with the technique of Farfan, being slightly more reliable than Pope’s method corresponding to the literature [29]. The techniques by Pope and Farfan have been validated in several studies [6, 15, 29]. We could confirm the highly significant correlation of both techniques [29].

Overall DHR

All patients considered DHR of the first adjacent disc ranged between 19 and 21%, that of the second disc between 14 and 16%.

Disc height is a known parameter correlating with the amount of disc degeneration [1, 26, 31]. DHR adjacent to fusion may be interpreted as degeneration in the context of the patients' general degenerative disease that has led to the initial fusion and keeps on going during FU in the non-fused segments, or it may be interpreted as reactive degeneration due to an altered biomechanical and biological situation following rigid fusion below.

Miyakoshi et al. [26] found a significant DHR of all adjacent discs in 45 patients (minimum FU 5 years) after fusion of L4/5 without any correlation between clinical results and DHR. They found a mean DHR of 7.8% for the first and 4.6% for the second cephalad adjacent segment. Kumar et al. [21] described adjacent DHR between 3.1 and 5.7 mm (minimum FU 30 years) after lumbar fusion. These results correspond well to our results.

On the other hand some doubt the deteriorating effect of fusion on adjacent segments [35]. Leong et al. [23] found radiological evidence of ASD in 53% of his patients (minimum FU 10 years), but the fact that these effects were worse in 1-level fusions than in 2-level fusions led them to the conclusion that it is unlikely that degenerative changes are significantly enhanced by fusion. Throckmorton et al. [33] found similar rates of ASD in patients, who were fused adjacent to an already degenerated disc at the time of surgery, and in patients who presented a normal adjacent disc at that time. They concluded that patients undergoing fusion do not suffer adverse effects from the creation of fusion adjacent to an already degenerated disc.

Our results show that despite differences between both the groups concerning underlying disease and age, altered biomechanics by fusion as the common factor of all patients, seems to contribute significantly to DHR.

Diagnosis groups

We found DHR in the adjacent disc of 23–25% in the degenerative group and of 11–12% in the listhesis group representing a tendency but not a statistically significant difference. This corresponds to the literature [11, 18].

The clear tendency towards a more pronounced DHR in the degenerative group shows that probably the underlying degenerative disease leading to surgery, in addition to the altered biomechanics by fusion, contributes to the amount of ASD.

Age

All patients considered DHR correlates with age resulting in advanced DHR with increasing age. Few studies exist describing DHR induced by aging in normal non-fused populations. Most of them did not find DHR with increasing age [32]. Our result showing a significant correlation of DHR with increasing age only in the older group 1 and not in the younger group 2 supports the thesis that age needs to be considered as risk factor especially as degeneration naturally advances with age. Statistically both factors (age and underlying degenerative disease) are not clearly distinguishable in this study, but are of clinical relevance in our opinion.

First versus second adjacent disc

Corresponding to the literature we could not find a significant difference between DHR of first and second disc [36]. But there was a trend towards fewer DHR in the second adjacent discs compared to the first. This has been described before [26, 37]. It supports the thesis that ASD is a result of the altered biomechanical situation that is more affected immediately next to fusion compared to second adjacent segments. Contrary others described similar rates of "breakdown" in first and second adjacent segments [15, 30].

Single versus multiple level fusion

Our results showed increased adjacent DHR in multiple level fusion patients. As biomechanics are more severely altered in multiple level fusion spines compared to one-level fusions, this supports the idea that altered biomechanics play a major role in the development of ASD. Several studies show that the incidence of ASD increases with fusion length [5, 13]. Only few studies doubt this [11].

Clinical results

DHR did not correlate with clinical improvement corresponding to the literature [18, 21, 26, 31]. Also in patients without fusion surgery, several studies found no correlation between DHR and low back pain [4]. So all presented radiographic findings have to be interpreted in perspective.

Proponents of disc arthroplasty argue that patients with artificial discs suffer from less ASD than patients with fused discs [10]. Our results allow careful doubts whether the radiographic adjacent DHR is of any clinical relevance. So prevention of ASD should not be seen to be the main argument for disc arthroplasty, limiting indications for artificial disc replacement.

Others

It could be hypothesized that ASD in non-floating could be more severe than in floating fusion patients. We did not find a significant difference between these groups. However, only five patients in our study had a floating fusion. So we are aware that this result needs careful interpretation.

Generally, preoperative MRI is the gold standard assessing discs. It could be hypothesized that preoperative assessment of the future adjacent disc using CT could be a reason for underestimation of a beginning DDD that could have been diagnosed using MRI (presenting, e.g. as dehydrated black disc). As in both diagnosis groups preoperative assessment was made using CT and MRI in the same proportion, the results of both groups are well comparable.

Limitations of the study include the lack of a control group and the relative heterogeneity of the study population.

Conclusions

Clinical results, 10 years after fusion show an improvement between 40 and 50% without a significant difference between patients with DDD and lytic spondylolisthesis.

Adjacent DHR amounts approximately 20%. This needs to be interpreted as disc degeneration. DHR in segments adjacent to lumbar fusion does not correlate with clinical outcome. So the clinical impact of adjacent DHR and ASD following fusion is weak. This allows careful doubts whether disc arthroplasty, whose philosophy bases on the idea to reduce ASD by maintaining mobility, will be far more successful compared to fusion. Our results may indicate that loss of adjacent disc height is a consequence of three factors: altered biomechanical loading next to a fusion, ongoing underlying degenerative disease affecting the entire lumbar spine and advancing age.

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