Anterior lumbar sagittal alignment after anterior or lateral interbody fusion

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A B S T R A C T

Purpose: Anterior or lateral interbody fusion is a treatment option for lumbar disc disease. A segmental change occurs after such surgery. This study was designed to evaluate the changes in the lumbar regional alignment after a single or two-level standalone anterior or lateral interbody fusion (ALIF or LLIF).

Methods: Data from patients referred to our institution between March 2013 and November 2015 for standalone ALIF or LLIF for low-grade isthmic spondylolisthesis or degenerative discopathy were retrospectively included in our analysis. Patients with a history of spinal fusion were excluded. Global and regional alignments were analyzed pre- and postoperatively. Pelvic tilt (PT), sacral slope (SS), sagittal vertical axis (SVA), lumbar lordosis (LL), index segmental lordosis (ISL) and L4S1 lordosis were compared. Three groups according to the pelvic incidence (PI) (low, normal and high) were separately analyzed then compared.

Results: Forty-one women and 27 men (mean age was 46 years; range 25–66) were included. The mean follow-up was 10.8 (range 3–34) months. The patients were globally well balanced preoperatively and remained after surgery (SVA stagnated from 16.76 ± 28.42 mm to 15.97 ± 28.20 mm, P = 0.75). PT and LL did not vary. L4S1 lordosis, and ISL were significantly increased respectively from 30.56 ± 8.59 to 34.58 ± 7.47 (P = 0.0026) and from 5.94 ± 5.25 to 12.99 ± 5.87 (P < 0.0001) at latest follow-up.

Conclusion: Despite effective changes in the segmental lordosis at the index levels, our findings suggest that one or two-levels standalone ALIF or LLIF had no effect on the global balance and the lumbar lordosis. The three groups behaved similarly, the regional lordosis was redistributed in a better harmony (L4S1/LL ratio went up from 55% to 61%, P = 0.01).

Study type: Retrospective study.

Level of evidence: 4.

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1. Introduction

Axial pain with radiculopathy, neurogenic claudication or instability may result from degenerative disc disease (DDD) or isthmic spondylolisthesis. Surgical treatment might be warranted, ranged from direct decompression only to decompression and fusion by posterior, anterior or combined accesses. The improvement of anterior accesses eases these procedures that are becoming every day more popular. One or multiple level anterior interbody fusion ensures direct access to the disc, restoration of the disc height, segmental lordosis and stability at the index levels. The aim of lumbar interbody fusion is not only to obtain a fusion, which is necessary to reduce the discogenic/radicular/facet joint-related pain, but also to improve the sagittal balance of the spine. On one hand, hypolordotic rigid fixation, resulting in malalignment of the lumbar spine, may increase the mechanical stress on the adjacent segment that accelerates the development of adjacent segmental failure [1]. On the other hand, we acknowledge that anterior and lateral accesses provide more lordotic correction than the transforaminal posterior access [2,3]. Furthermore, a patient with a high pelvic incidence (PI) needs a high lumbar lordosis (LL) [4]. Thus, patients with a high PI and an insufficient LL on preop. standing X-rays need a high lordotic correction [5]. Consequently, the anterior and lateral interbody fusions are preferable to the posterior one so as to achieve a better lordotic anterior column realignment.

The spino-pelvic parameters play a major role in planning the anterior column reconstruction. Pelvic incidence-lumbar lordosis mismatch is the major guide to determine the optimal final
alignment after surgery and thus determine the adequate access: anterior rather than posterior access seems, intuitively, preferable in high pelvic incidence. We assume that optimal distribution of the lumbar lordosis leads to less adjacent segment failures and theoretically better functional results.

In this study, we focused on the radiological alignment and the distribution of the segmental lordosis. Our hypothesis was that anterior one or two-levels standalone interbody fusion for isthmic spondylolisthesis or degenerative discopathy had no effect on the global sagittal balance but allowed a harmonic realignment of the elliptic lordosis of the lumbar spine.

2. Methods

All adult patients referred to the neurosurgical department of the University hospital of Lille bearing a symptomatic lumbar degenerative disc disease or a low-grade isthmic spondylolisthesis and treated with a standalone single or two-level retroperitoneal lumbar interbody fusion between March 2013 and November 2015 were retrospectively included in our study. Exclusion criteria comprised:

- a spinal surgery history other than lumbar disectomy or foraminotomy;
- cases of posterior fixation performed to complete the anterior fusion.

2.1. Surgical technique

The interbody fusions were performed through a retroperitoneal approach, either anterior (anterior lumbar interbody fusion [ALIF], or lateral (lateral lumbar interbody fusion [LLIF]). The choice of the approach (ALIF or LLIF) was made according to which vertebral level was to be treated and the vascular anatomy of the patients. To assess the accessibility of the discs with regard to the iliac vessels, all patients underwent a preoperative tridimensional CT angiogram.

2.1.1. ALIF

The patients were placed in French position (supine position with legs apart) with a slight hyperextension of the lumbar spine.

The intervertebral disc was approached by a midline horizontal incision after a fluoroscopic location of the level. The whole intervertebral disc was removed, and a PEEK cage was placed. The size of the cage was adapted to the normal adjacent discs, and the lordosis chosen according the spino-pelvic parameters of the patient, especially the pelvic incidence. The theoretical segmental lumbar lordosis was determined in relation with the pelvic incidence of the patient [5], and the angulation of the lordotic cage was chosen according to the elliptic representation of the lumbar spine as described by Janik et al. [6]. Practically, we chose a cage whose lordosis would make L4S1 lordosis as close as two third of the lumbar lordosis as possible. The cage was filled either with bone substitute combined to bone marrow taken from the iliac crest, or with dibotermine alpha (InductOS® Medtronic).

2.1.2. LLIF

Patients were placed in lateral decubitus, slight extension of the ipsilateral leg. The side of the approach is usually from the left. After a retroperitoneal approach, the disc was removed through an anulotomy. A dedicated interbody device is then placed by impaction, previously filled by bone substitute.

All the patients had a clinical examination and a full-spine standing radiograph in an EOS imaging® cabin before the surgical procedure (T0) as well as at 3 months after surgery (Tp) and at the last visit (TF). All data were compiled in Keops Data Manager (SMAIO®, Lyon, France).

2.2. Radiological data

The radiological parameters were serially measured at T0, Tp and TF. All full-spine standing radiographs were analyzed using Keops SB Analyzer (SMAIO®, Lyon, France) [7]. Fusion status was assessed on standing radiographs and confirmed by multplanar CT-scan reconstructions.

2.2.1. Spino-pelvic parameters

We measured the spinal parameters (cervical lordosis Cl, thoracic kyphosis TK, and lumbar lordosis LL), and the pelvic parameters (pelvic incidence PI, pelvic tilt PT, and the sacral slope SS). The lumbar lordosis was measured as the angle between the thoracolumbar inflexion point and the sacrum.

2.2.2. Global sagittal balance parameters

The sagittal balance of the patients was assessed by the sagittal vertical axis (SVA) and the spinosacral angle (SSA).

2.2.3. Segmental lumbar sagittal alignment: segmental lordosis angles

The segmental distribution of the lumbar lordosis was assessed measuring the index segmental lordosis angle (ISL), and L4S1 angle (Fig. 1 a and b).

2.3. Statistical analysis

After checking the absence of correlation between the follow-up delay and the evolution between T3 and TF, analyses of repeated measurements were performed by using the linear mixed model (LMM) to test both the time effect (T0, Tp, TF) and the 3 classes of PI (10–45],[45–55] and [55–]). Interaction between time and PI classes was also tested. When time or PI classes were significant, post-hoc tests were performed using contrasts.

Statistical analyses were performed using the SAS Software V9.4 (SAS Institute, Cary, USA). Graphical representations were realized with Excel (Microsoft TM).

3. Results

3.1. Population

Two hundred and twenty-two patients underwent a ALIF or LLIF during the considered period. Sixty-eight consecutive patients did not respond to the exclusion criteria and were included in the study. There were 27 men and 41 women with a mean age of 46.26 years. All demographic data are compiled in Table 1.

3.2. Operative parameters

The approach was anterior (ALIF) in 51 cases (75%) and lateral in 17 cases (25%). A total of 74 discs were fused. Operated level was L3L4 in 6 cases, L4L5 in 19 cases, and L5S1 in 48 cases. Mean cage height was 12 mm ± 2 (range 8–16), and mean cage lordosis was 10° ± 2.6° (range 6–14°).

Hospital stay duration was 5.8 ± 1.53 days (range 3–10). No vascular, urogenital or infectious complications occurred during or after surgery. Non-fusion was observed in 4 patients (5.8%), and adjacent disc degeneration in 3 patients (4.4%). These patients had to undergo a revision surgery.
Table 1
Demographics.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>46.26 ± 9.84 (range 25–66)</td>
</tr>
<tr>
<td>Gender</td>
<td>Female 41; male 27</td>
</tr>
<tr>
<td>Previous spinal surgery</td>
<td>Foraminotomy 5</td>
</tr>
<tr>
<td>Pathology</td>
<td>Degenerative discopathy 51</td>
</tr>
<tr>
<td>Procedure</td>
<td>SSA: 51</td>
</tr>
<tr>
<td>Implants</td>
<td>RofA (LDR): 37</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>5.8 ± 1.53 days (range 3–10)</td>
</tr>
<tr>
<td>Fusion rate</td>
<td>94.2% (n = 64)</td>
</tr>
<tr>
<td>Adjacent disc degeneration</td>
<td>4.4% (n = 1)</td>
</tr>
</tbody>
</table>

Table 2
P values for SVA and SSA evolution between T0 and Tp, between Tp and Tf, and between T0 and Tf.

<table>
<thead>
<tr>
<th>P values</th>
<th>T0–Tp</th>
<th>Tp–Tf</th>
<th>T0–Tf</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVA</td>
<td>0.98</td>
<td>0.731</td>
<td>0.750</td>
</tr>
<tr>
<td>SSA</td>
<td>0.823</td>
<td>0.594</td>
<td>0.450</td>
</tr>
</tbody>
</table>

3.3. Radiological outcomes

3.3.1. Global sagittal balance

Pelvic incidence was 52.77 ± 13.49. The population was divided into 3 groups of PI: PI 1 [0–45], n = 19; PI 2 [45–55], n = 16 and PI 3 [55–], n = 33. According to Roussouly’s classification [8], there were 22 type 1, 25 type 3, and 21 type 4. Global sagittal balance was good for the whole population, with a mean preoperative SVA of 16.7 ± 28.4 mm, and SSA 128 ± 10.4.

The global sagittal balance of the patients was good and remained so after the surgery (no significative P for SVA and SSA between T0 and Tf) (Table 2).

3.3.2. Spino-pelvic parameters

PT, SS, CL, TK, LL and were not significantly modified (Table 3 and Fig. 2), between T0, Tp, and Tf, for the 3 PI classes.

Table 3
P values for PT, SS, CL, TK and LL evolution between T0 and Tp, between Tp and Tf, and between T0 and Tf.

<table>
<thead>
<tr>
<th>P values</th>
<th>T0–Tp</th>
<th>Tp–Tf</th>
<th>T0–Tf</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT</td>
<td>0.949</td>
<td>0.475</td>
<td>0.515</td>
</tr>
<tr>
<td>SS</td>
<td>0.808</td>
<td>0.628</td>
<td>0.467</td>
</tr>
<tr>
<td>CL</td>
<td>0.539</td>
<td>0.601</td>
<td>0.257</td>
</tr>
<tr>
<td>TK</td>
<td>0.900</td>
<td>0.818</td>
<td>0.916</td>
</tr>
<tr>
<td>LL</td>
<td>0.787</td>
<td>0.718</td>
<td>0.528</td>
</tr>
</tbody>
</table>

3.3.3. Segmental lumbar lordotic alignment

ISL and L4S1 significantly increased between T0 and Tf (P<0.001 and P=0.0071), L4S1/LL ratio also significantly increased (P=0.0032) (Table 4, Figs. 3–5). As the LL remained constant and L4S1 lordosis increased, the cranial segments of the lumbar spine, that is to say the unfused segments, decreased. The changes were significant between T0 and Tp, and between T0 and Tf, but not between TP and Tf, meaning that the ISL, L4S1 and L4S1/LL ratio remained constant between 3 months and last visit. These results were obtained in the 3 PI classes.

3.3.4. Illustrative case

A 32-year-old female patient suffered from chronic low back pain associated to a mechanical right crural pain. The MRI showed L3–4 and L4–5 degenerative discopathy, and standing EOS full-spine radiographs showed a good sagittal balance (SVA = 14 mm), but an insufficient L4S1 segmental lordosis (L4S1/LL = 45.6°). The patient underwent a L3–4 and L4–5 LLIF, which kept the sagittal balance good (SVA = −4.4 mm), and increased L4S1 lordosis (L4S1/LL = 50.7°) (Fig. 6a and b and Table 5).
4. Discussion

In our study, we focused on the radiological changes of the lumbar curvature in patients who underwent one or two-levels ALIF or LLIF as a treatment option for a low-grade spondylolisthesis or degenerative disc disease.

Our findings suggest that the anterior approach is effective in improving the lordosis at the index segment (ISL). The patient were globally balanced before the surgery with a preoperative SVA = 16.7 ± 28.4 mm, and remained so after surgery \(P=0.750\). The L4–S1 lordosis and the ISL have been significantly increased \(P=0.0071\) and \(P<0.0001\). As the lumbar lordosis has not been
According to Roussouly’s classification, one third of the patients were type 1, one third were type 3, and one third were type 4. The patients were classified using Keops® software, according to their spino-pelvic parameters. We believe that some type 1 patients were actually type 2, but we wanted to keep a repeatable way of sorting our patient.

What is important to note here is that there was no improvement of sagittal balance, which was already good, but a preservation of it. Therefore, we hypothesized that this approach was efficient in achieving a more physiological redistribution of the lumbar lordosis, in patients who initially harbored no significant sagittal imbalance. Janik et al. [6] showed that the best representation of the lumbar lordosis is that of a portion of an ellipse, meaning that the segmental lordosis in the lumbar spine are increasingly high from L1 to the sacrum, with about two third of it between L4 and the sacrum. We think that a local redistribution of the lumbar lordosis is one of the first mechanisms to compensate an anterior unbalance, and that ALIF and OLIF in globally balanced patients correct this remodeling, making the lumbar spine a portion of an ellipse again.

Lumbar fusion is an efficient treatment for various degenerative conditions, such as degenerative disc disease, spondylolisthesis and deformity. Over the past decades, improvement in surgical techniques and spinal instrumentation allowed surgeons to perform safe and solid constructs. Moreover, the increasing use of cages and various graft materials has lead to dramatically improved fusion rates and patients’ outcomes. Thus, epidemiological studies demonstrated that the number of lumbar fusion increased 2.4-fold (113%) between 1998 and 2008 in the United States, which is much greater than increases in other major orthopedic procedures [9]. Although lumbar fusion is an effective and increasingly performed treatment, there is still no consensus regarding the ideal approach.

The anterior approaches have gained more popularity because it allowed a direct access to the disc space, sparing the spinal musculature and avoiding the need to dissect or tract the neural structures.

Moreover, many surgical teams strongly believe that this approach offers the advantage of releasing the anterior longitudinal ligament [10], and of insertion of an adequately sized cage, with sufficient anterior placement to obtain maximal lordosis of spinal segments, leading to better correction of spinal balance. However, the changes achieved on the local and global lumbar lordosis after one or two-levels ALIF or LLIF have not been well assessed to date. Our study has a few limitations that are noteworthy. In fact, none of the patients included in this study harbored a sagittal imbalance, so the current cohort only represents a specifically selected population. In particular, this study does not allow us to understand how anterior inter body fusion may improve alignment globally in an unbalanced spine. In addition, all patients included hereby had undergone an anterior approach and there is no control group to confirm the superiority of ALIF over the posterior approach.

Table 5

<table>
<thead>
<tr>
<th>PI</th>
<th>Pl1</th>
<th>Cr1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL</td>
<td>45.74</td>
<td>51.86</td>
</tr>
<tr>
<td>ISL (L3/4)</td>
<td>11.4</td>
<td>9.38</td>
</tr>
<tr>
<td>ISL (L4/5)</td>
<td>16.13</td>
<td>20.89</td>
</tr>
<tr>
<td>L4S1</td>
<td>20.88</td>
<td>26.81</td>
</tr>
<tr>
<td>L4S1/LL</td>
<td>45.65</td>
<td>51.7</td>
</tr>
<tr>
<td>SVA</td>
<td>14.4 mm</td>
<td>−4.4 mm</td>
</tr>
</tbody>
</table>

Fig. 6. Illustrative case: 32 years female patient suffering from chronic back and crural pain. Preoperative full-spine standing X-ray (left, a) shows kyphotic degeneration of L3/L4 and L4/L5 discs. Preoperative L4S1/LL ratio was insufficient. The right picture (b) displays the radiological control at the last visit after a two-level LLIF.

Table 2 reports T0 and T1 radiological parameters for the illustrative case.

Fig. 5. Mean values of L4S1/LL ratio at T0, Tp and Tf.
with regard to redistributing the lumbar lordosis. Thus, we cannot conclude after this study that improving the lordotic ellipse and segmental alignment could be obtained more or less easily with a posterior interbody fusion. Finally, we have not analyzed the patients' clinical and functional outcomes. Although, we trust that improvement of lumbar lordosis distribution will lead to better outcomes over the long term, this needs to be assessed in a longitudinal follow-up study. Postoperative disability after a lumbar fusion has multiple etiologies; iatrogenic adjacent segment pathology might be one of them. Postoperative hypolordotic realignment is identified as one of the possible factor that induces adjacent disc disease by increasing the mechanical stress on the transitional zone. The transitional segment is affected by a “stress concentration” due to the rigidity of the instrumentation below, and this is amplified in case of abnormal alignment (kyphosis) that increases – as a compensation mechanism – the segmental lordosis at that segment and shifts the loads posteriorly. These statements call for studies on long-term clinical and radiological results to assess whether the redistribution of lumbar lordosis can limit the occurrence of adjacent disc disease and especially to determine if there is a clinical impact. In this study, the adjacent disc disease rate was 4.4%, which is relatively high in regards with the short follow-up period. After analyzing the 3 concerned patients, we noted that this was due to degenerative lesions that were already present at time of index surgery. We first decided not to operate on these discs since the segmental lordosis were preserved at these levels.

5. Conclusion

One or two-level anterior or lateral lumbar interbody fusion for degenerative discopathy or low-grade spondylolisthesis had, in our study, no significant effect on the global sagittal balance, and on the lumbar lordosis. What was observed was a redistribution of the lumbar lordosis, which tended to be like the portion of an ellipse again. In conclusion, we believe that these procedures permit to obtain very good fusion rates, and are useful to correct the lumbar degenerative disorganization, especially in patients with high pelvic incidences.

Disclosure of interest

The authors declare that they have no competing interest.

References