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Maintenance of Disc Height and Lordosis When Performing a New Technique In Instrumented Lumbar Posterolateral Fusion

- Results from a Consecutive Prospective Study –

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Abstract

Study Design: Consecutive Prospective Study.

Summary of Background Data: Lumbar fusion is considered the "gold standard" treatment for chronic low back pain (CLBP) that is believed to be due to degenerative disc disease (DDD) and is not relieved by prolonged conservative treatment. Instrumented intercorporal fusion is believed to restore disc height and prevent postoperative kyphosis better than instrumented posterolateral fusion (PLF). A new technique to perform PLF, using modern pedicle screw systems, challenges this belief.

Objective: This study has two main objectives: to measure disc height and segmental lordosis pre-, post-, and late post-operative in patients operated on with a variant of PLF and to compare the results with reported measurements with other techniques.

Material: The study included 97 consecutive patients (56 female) age 20-73, all with CLBP; 84 patients were diagnosed as DDD only, 13 patients had a spondylolisthesis with concurrent DDD. Forty-nine, patients were treated at one segment, 47 at two segments, and one patient at three segments. All patients were X-rayed preoperatively, immediately post-operative, and at late follow-up (≥ 10 months).

Methods: In all patients, PLF's were performed using a pretension-distraction technique. Disc height and lordosis were calculated for all treated segments according to evaluated methods. The values on disc height and lordosis were compared for each patient preoperatively, immediately post-operative, and at follow-up.

Results: All treated segments had an increase of disc height at post-operative examinations. Despite some reduction of this increase at late control follow-up, the increase was still significant for L3-L4 segment (men) and L4-L5 and L5-S1 segments (women). Lordosis was reduced postoperatively with less than the measurement error for the method.

Conclusions: When this method of PLF was used, long-term increase in disc height and maintenance of lordosis was as favorable as reported on intercorporal fusions.

Keywords: PLF; Distraction; Late follow-up; Disc height; Lordosis

Introduction

Chronic low back pain (CLBP) often causes sick leave, pain, dysfunction, and reduced quality of life [1-5]. Degenerative disc disease (DDD) is regarded as the most common cause of CLBP and may often lead to "disc space narrowing" (DSN) [6]. Pain due to DSN is believed to be caused by two mechanisms. On being the abnormal motion pattern that develops due to DDD in the affected segment, causing discogenic pain. Another one is being a reduction of foramen space, which might conflict with nerve roots, causing radiculopathy [7].

The cause of CLBP due to DDD is multifactorial. However two of the more important factors seem to be loss of disc height and reduced lordosis ("flat back") [7-13]. Although there are contradictions [14,15], the majority of recent studies support the association between DSN and LBP [8-13]. For instance, Lidar et al. noted that when morbidly obese people lost a significant amount of weight, disc height increased and LBP was reduced [12]. Also, according to Djurasovic et al., it seems severe DSN on MRI is more coherent with good clinical outcome than other MRI criteria, frequently used for selecting patients whom might be suited for lumbar fusion [13]. DSN is also associated with loss of lumbar Lordosis and loss of lumbar lordosis after fusion increases risk of adjacent segment disease (ASD) [16-18]. Global sagittal balance restoration is achieved by restoring as much lumbar lordosis as possible. Consequently, it seems highly warranted for the surgical goal of spinal fusion to go beyond just fixing the motion segment. Surgery should also strive for restoring anatomical structure and alignment by reducing DSN [7] in order to decrease CLBP and avoid development of ASD [8-13,16-19].

Today, several treatment options exist for CLBP [1,20-22]. The first choice of treatment is prolonged conservative therapy, including physical exercise and multi-professional rehabilitation [23,24]. If conservative treatment fails and surgery is considered, fusion of painful segments is regarded the "gold standard" [24,25]. Extensive experience has lead to the development of several techniques, but there is no general consensus as to which method of fusion is the best [6,20,21,26,27].

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The most widespread technique is "posterolateral fusion" (PLF), where bone transplants are placed to bridge the transverse processes and the facet joints. Many fusions are "intercorporal", where bone transplants and supports are placed between the endplates of two adjoining vertebra. These fusions are named after the approach used: posterior lumbar interbody fusion (PLIF), anterior (ALIF), transforaminal (TLIF), etc. Today, most fusions are instrumented [20].

According to Fritzell et al., instrumented PLF is more resource effective than intercorporal fusions in terms of operation time, blood transfusion, and days in hospital after surgery [20]. However, there are studies stating that PLF does not maintain/restore disc height, or is not as effective in doing so as PLIF [16,22].

Posterolateral fusion, is less invasive than intercorporal fusion [20], and might reduce the risk of neurological complications associated with PLIF [28,29]. New stable pedicle screw instruments offer possibilities to perform PLFs that beyond counteracting pathological motion patterns also might better restore disc height and lordosis. This prospective study examines whether this can be done when performing instrumented PLF without anterior support between vertebral endplates.

Ethical considerations

PLF in different manners have been performed on this indication for a long time, and have shown little differences in clinical and surgical (anatomical restoration) results compared to intercorporal fusions [6,20,21,26,27]. Since the result of this new technique might be as good as, or if successful, better than intercorporal fusions we did not judge that an ethical problem existed. Furthermore, the surgeon has used this technique on occasions since the early nineties without the occurrence of any new or added complications. This study was based on the analysis of radiographs taken on patients for pure clinical purposes. No participants were exposed to any added X-ray examinations due to this study.

Objective

This study aims to evaluate an altered technique to perform posterolateral fusions and reveal whether this technique increases disc height and lordosis in a comparable amount as intercorporal fusion. Thus, the outcome is our radiographic measurements and calculations. The connection between radiographic findings and clinical outcome has been acknowledged in many studies prior to this one, why we consider it to suffice as outcome in this study. Depending on our results there might be cause for a new study, determining the impact on clinical outcome. The study also investigates which patient group received this treatment and at what segments.

Materials and Methods

All patients were treated by the same surgeon (SB) between 2003 and 2009. The treatments were performed between L3 and S1 using instrumented PLF. To be included in the study, the patients had to be operated with the below described type of PLF technique for the indication DDD. DDD was defined as CLBP where no other etiology (e.g. hernia, scoliosis, stenosis) could be demonstrated clinically, through radiology or other methods. DDD in combination with degenerative spondylolisthesis, was included. DSN on plain X-ray had to be demonstrated preoperatively. Surgical indications were: CLBP due to DDD for more than one year where conservative treatment had proved ineffective. All patients that were judged suitable for this method were treated with it and subsequently included in the study. Patients with obvious signs of osteoporosis/osteopenia, and patients previously treated with fusion or total disc replacement were not included as the described procedure was not suitable in these cases. No randomization was used.

All of the 121 patients treated with this type of instrumented PLF were originally evaluated for inclusion in the study. Due to the inability to retrieve a complete set of X-ray examinations in 24 patients, only 97 were finally included in the material. The material consisted of these 97 consecutive patients (age 20-73, mean 48) all with more than a year of CLBP that was not relieved by conservative treatment. Fifty-six patients were female (age 20-73, mean 50) and 41 men (age 25-63, mean 45). Eighty-four patients (49 female, 35 male) were diagnosed with only DDD, and 13 patients (7 female, 6 male) had a spondylolisthesis of L5-S1 with concurrent DDD at L4-L5. Forty-nine patients (27 female, 22 male) were treated at one segment, 47 (28 female, 19 male) at two, and one female patient at three segments for a total of 146 segments treated and examined. Fusion of three segments was rarely performed, and only when discography was positive for three adjacent segments with severely degenerating discs. Plain lateral lumbar spine X-rays acquired between eight years and one day before surgery was collected. In addition, films taken after surgery (two days after) and at late examination (minimum ten months to six years, mean: 19 months) were collected. Hence, a total of 291 films were gathered, taken between 1997 and 2011. Patients were positioned in standard recumbent position. The majority of films were collected from Stockholm Spine Center archives. If films were not found there, they were retrieved from the participants' home clinic.

A radiologist evaluated radiological fusion from follow-up films. Radiological fusion was either approved or not. Fusion after PLF is relatively easy to confirm on plain x-ray since the bony fusion is lateral. If fusion could not be confirmed or was uncertain, a CT was made to enhance the evaluation. Fusion was achieved in the same frequency if sagittal malalignment was present preoperatively or not.

All instrumentations were with the Monarch rod and poly-axial screw-system (DePuy Spine, Raynham, MA, USA), which allows for compression/distraction after the angle of screw relative to the rod is locked.

Surgical method

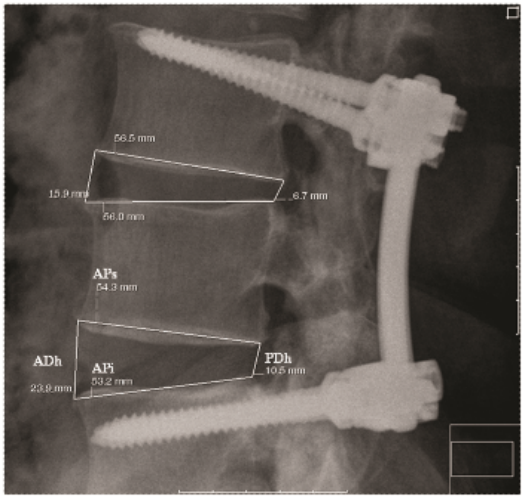
After the posterolateral preparation, pedicle screws were placed bilaterally at the upper and lower segment to be fused (i.e., only four screws were used irrespective of the number of segments fused). The screws were attached to connectors that slid on the rods, one at each side. While the angle between the screws and the rods were still mobile, the screws on each side were compressed towards one another and the angulations were locked. This maneuver pre-tenses the system to prevent the development of post-operative kyphosis and loss of lordosis intra-operatively. The operative goal of sagittal correction was to restore as far as possible a lordotic curve at the index segments. This was controlled intra-operatively with C-arm fluoroscopy. Pelvic incidence was not taken into account. After this pre-tension, distractive force was applied to the screws, so the connectors slide apart on the rods to increase disc height. Next, the connectors were fixed to the rods. The surgical procedure was performed by the same surgeon for all the patients in this study. No direct decompression was performed.

Measurement method

All radiographs were viewed and measured in AppGate Client version 8.1.1 (© Sectra Imtec AB, Sweden, 2007 Sectra Imtec AB, Teknikringen 20, 583 30 Linköping, SVERIGE) or IMPAX Client version 6.4 SU01 (2009 Agfa HealthCare N.V., Septestraat 27, B-2640, Mortsel, Belgien) computer program, using each program's tool for distance and

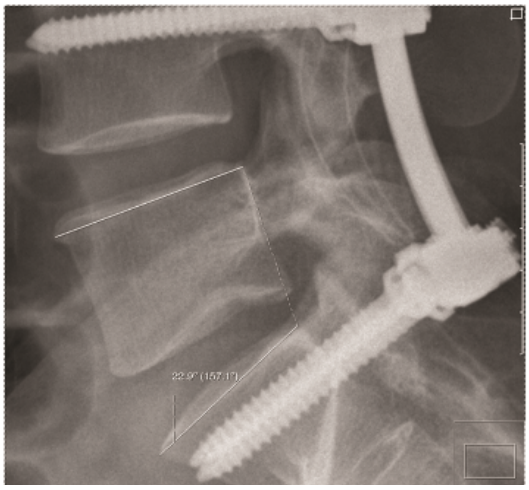
angulations. Disc space and lumbar lordosis were measured on lateral radiographs with patients positioned in a recumbent neutral position on preoperative, postoperative, and late follow-up radiographs. Disc space was defined as the whole translucent vertical distance between the adjoining vertebrae [30]. Disc height and depth was measured according to Farfan's method [31]. Four landmarks were marked on the "corners" of the vertebral bodies superior and inferior to the index disc on each radiograph. These marks defined the disc space. Lines were drawn between the landmarks and measured (Figure 1). The mean of anterior (ADh) and posterior (PDh) distance between landmarks was taken as disc height (Dh=ADh+PDh)/2). Disc depth or anteroposterior diameter of the disc was defined as the mean of the superior (APs) and inferior (APi) disc depth measurements (Dd=(APs+APi)/2) [32,33]. Compensate for magnification, disc height was divided with disc depth, giving a non-dimensional index of disc height. In other words, a disc with the depth of 44.9 mm (mean) and a measured index of 0.297 has a disc height of 13.3 mm (44.9×0.297=13.3). The criterion for positioning of the landmarks for the discs was that the marks should be on the extreme anterior and posterior margins of the end plates of the vertebrae, which gave the method a measurement error (ME) of 0.75 mm [32].

Segmental lordosis was measured using conventional Cobb's two line technique (Figure 2) [34]. Lines were drawn along the superior endplate of the vertebral body inferior in relation to the disc and the superior endplate of the vertebral body superior to the disc. Using the two lines Cobb technique human error is reduced, compared to Cobb's original four line technique, since there are half as many lines to be drawn and because angle calculation is made digitally instead of with manual instruments [35]. The angle between the lines was calculated in the digital picture programs described above. According to Harrison et al. ME is 1.6 degrees using this technique. This could be compared to using Cobb's manual four line technique which has a ME of 4.6 degrees [34-36]. The results consisted of the differences between pre- and post-operative values, pre- and late post-operative values with respect to post- and late post-operative values for disc height and lordosis. All



Measurement of disc height using a computer program (see text). Mean of anterior and posterior disc height was calculated (Dh = ADh + PDh/2). To compensate for magnification between films, Dh was divided with mean of disc depth (Dh/(APs+APi/2)

Figure 1: Measuring of disc height.



Segmental lordosis was measured as the angle between the superior endplate of inferior vertebrae and superior endplate of superior vertebrae. The computer program (see text) calibrated the angle.

Figure 2: Measuring of segmental lordosis.

measurements were performed by one of the authors (PS). To calculate reliability of the calculated differences, every fifth patient (selected by day, month, and year of birth) was re-measured by the other author (SB).

Statistics

The mean (M), standard deviation (SD), and confidence interval (CI) for disc height and segmental lordosis were calculated. The statistical significance level of measured differences between preoperative, postoperative, and late follow-up values was set to 0.05 (P). Statistics were performed with Statistica, version 10 (StatSoft Inc. Tulsa, OK, USA). For differences between pre- and post-operative values, as well as for differences in late follow-up values, Students t-test for dependent values and ANOVA was used. To estimate reliability of differences between pre-, post, and late postoperative measurements, Lin's concordance correlation coefficient was calculated.

Results

The most common surgery was fusion performed on segments L4-S1 (i.e., two segments) with a total of 36 patients (19 female, 17 male). In single segment fusions, L5-S1 was treated in 29 participants (17 female, 12 male), L4-L5 as a single segment was treated in 18 patients (9 female, 9 male), and only L3-L4 was treated in two participants (1 female, 1 male). Segments L3-L5 was fused in ten participants (8 female, 2 male). Triple segment fusion was only performed on one female on segments L3-S1. After surgery, all segments had a significant increase of disc height from pre-operative films to postoperative films (Table 1). The fusion rate was 94%. There was some loss of this increase at late control follow-up, but the increase was still significant for the entire group and for women specifically in L4-L5 and L5-S1 segments. In the L3-L4 segment, the increase of disc height was significant for men, but not for the entire group or the women separately at late follow-up. The largest significant increase was in the L3-L4 segment in men however this was the smallest group; the second largest increase was in the L5-S1 segment in women.

Change in disc height was calculated and described as the ratio declared in the method part. The total increase of disc height in the

whole group in treated segments was on average 0.085 (SD=0.048, P=0.000) postoperatively and 0.036 (SD=0.063, P=0.000) at late follow-up. Using average disc depth (44.938 mm), this corresponds to approximately 3.817 mm and 1.618 mm, respectively. For females, the figures were 0.094 (SD=0.050, P=0.000) and 0.048 (SD=0.066, P=0.000), respectively. For men, the figures were 0.073 (SD=0.042, P=0.000) and 0.020 (SD=0.056, P=0.033), respectively. Women younger than 40 years displayed the largest increase (0.462 to 0.559) of disc height postoperatively and at late follow-up (0.462 to 0.525) compared to preoperative values (P=0.000 and P=0.007, respectively). Significant loss of disc height between post-operative and late follow-up was observed in the L4-L5 segment in men (P=0.000). All changes in disc height from pre-operative to late follow-up, except in L4-L5 and L5-S1 in men, were above ME for the method (0.75 mm). This corresponds to a ratio of 0.0165 when ME is divided by average disc depth.

The change of lordosis from preoperative to postoperative follow-up is presented in Table 2. Lumbar lordosis decreased in all but one segment, but there was a discrepancy between genders in both the L5-S1 and the L4-L5 segment. Men's lumbar lordosis in L5-S1 decreased by 14% postoperatively, and totally by 25% at late follow-up (3.0° (P=0.028) and 5.2° (P=0.001), respectively). Women displayed no significant decrease of lordosis in the L5-S1 segment. In the L4-L5 segment, women's lumbar lordosis decreased by 14% postoperatively and totally by 28% at late follow-up (1.8° (P=0.162) and 3.5° (P=0.008), respectively). Men's lordosis decreased by 3% postoperatively but increased totally by 10% at late follow-up (0.4°, (P=0.790) and 1.2° (P=0.447), respectively). There was no significant decrease of lordosis observed for either women or men in the L3-L4 segment.

When each treated segment's angle were summed (total lordosis)

Segment & participants	TOM & P-value	All participants	Female	Male
L5-S1 **F=37** **M=29**	Pre-op	0.278 (0.069)	0.275(0.084)	0.281 (0.043)
	Post-op	0.339 (0.074)	0.350(0.086)	0.324 (0.052)
	P-value	***0.000***	***0.000***	***0.000***
	Late follow up	0.305 (0.079)	0.314(0.095)	0.294 (0.054)
	P-value	***0.000***	***<0.001***	0.124
L4-L5 **F=37** **M=28**	Pre-op	0.267 (0.064)	0.267(0.067)	0.268 (0.059)
	Post-op	0.322 (0.060)	0.322(0.065)	0.322 (0.055)
	P-value	***0.000***	***0.000***	***0.000***
	Late follow up	0.287 (0.067)	0.296(0.072)	0.275 (0.061)
	P-value	***0.000***	***0.000***	0.268
L3-L4 **F=11** **M=3**	Pre-op	0.239 (0.049)	0.236(0.051)	0,250 (0.048)
	Post-op	0.290 (0.052)	0.281(0.050)	0,324 (0.056)
	P-value	***0.000***	***0.007***	***0,013***
	Late follow up	0.269 (0.056)	0.258(0.056)	0,311 (0,042)
	P-value	0.067	0.166	***0,014***

Mean disc height, described as actual measured height divided with depth of disc (see figure. 1) before operation, immediately post-op examination, and examination late follow up. Dh= disc height. Time of measurement (TOM). P-value of change from preoperative examination. P-value <0.05 has been highlighted. In between brackets = Standard deviation (SD).

Table 1: Change in disc height. Preoperative, postoperative, and late follow-up in all participants, women and men (both single and multiple segment fusions).

Segment & participants	TOM & P-value	All participants	Female	Male
L5-S1 **F=37** **M=29**	Pre-op	20.4 (6.4)	19.8 (7.3)	21.1 (5.1)
	Post-op	18.0 (5.6)	17.9 (6.2)	18.1 (5.1)
	P-value	***0.006***	0.177	***0.000***
	Late follow up	16.7 (6.3)	17.3 (6.6)	16.0 (6.0)
	P-value	***0.000***	0.064	***0.000***
L4-L5 **F=37** **M=28**	Pre-op	12.3 (5.7)	12.7 (5.8)	11.7 (5.6)
	Post-op	11.1 (4.9)	10.9 (5.3)	11.3 (4.4)
	P-value	0.057	***0.030***	0.690
	Late follow up	10.8 (5.8)	9.2 (5.3)	12.9 (5.9)
	P-value	***0.036***	***0.000***	0.289
L3-L4 **F=11** **M=3**	Pre-op	7.0 (3.9)	7.6 (4.3)	9.6 (1.9)
	Post-op	6.2 (4.4)	5.8 (4.7)	7.3 (1.6)
	P-value	***0.045***	0.110	0.327
	Late follow up	6.9 (4.8)	7.0 (5.2)	6.6 (3.4)
	P-value	0.244	0.535	0.383
Multi-segment. treated **F=29** **M=19**	Pre-op	29.8 (11.7)	29.3 (12.8)	30.7 (10.0)
	Post-op	26.2 (10.3)	25.4 (11.7)	27.5 (7.7)
	P-value	***0.005***	***0.035***	0.060
	Late follow up	25.0 (10.9)	23.6 (11.7)	27.2 (9.4)
	P-value	***0.000***	***0.000***	0.074

Mean change in segmental lordosis. Mean change in total lordosis, for patients treated in more than one segment. P-value has been calculated for change between pre- and post operative X-ray examination, and for change between preoperative and late follow up. P-value <0.05 has been highlighted. Time of measurement (TOM). In between brackets = Standard deviation (SD)

Table 2: Change in lordosis. Preoperative, postoperative and late follow up in all participants, women and men.

in subjects operated at two or more segments, both men and women had a numerical loss of lordosis at late follow-up, but this change was not significant for men. There was no statistically significant difference between people older than 41 and people younger than 40. For the group in total and for treated women, disc height increase in L5-S1 and L4-L5 correlated with increase in lordosis. The result in the reliability estimation between the two measurers was a Lin's coefficient of 0.91, indicating a very high repeatability of the used methods.

Discussion

When performing lumbar fusions in patients with DDD, spondylolisthesis, or these two diagnoses in combination, it is common that effort is spent on increasing disc height. There are four reasons for increasing height:

1. Increasing disc height is an important step in correcting sagittal mal-alignment i.e. global sagittal balance restoration.
2. An increased disc height will increase the diameter of the exiting nerve foramina [19].
3. An increased disc height will reduce tendency for the segment to shift into kyphosis.
4. In non-operated patients, decrease of disc height seen on radiology has been closely correlated to low back pain [8-10] whether the loss of disc height in itself produces pain or the height reduction is merely a visible sign of painful disc degeneration remains unclear.

Usually, it is considered mandatory that an anterior support between endplates is added (cage, tri-cortical bone grafts, or disc prosthesis) if the intention is to increase disc height and resist kyphosis.

This prospective consecutive study investigates the patient material that the above described technique was used on and reveals whether the intention to achieve an increased disc height was fulfilled in a short perspective as well as in a long enough perspective for fusion to take place. The fusion rate in this study was 94%. There is an immense variation reported on fusion rates for other surgery methods. Fusion rates for PLIF varies from 65% to 95% [20,22,28]. For TLIF (combined with growth factors) from 90%-99% [47] and for ALIF it is 92% [49]. Fusion rate for PLF with this technique seems to be comparable to other methods.

There was a significant increase of disc height in all treated segments in women and in the L4-L5 and L5-S1 segments for men soon after the operation. Strikingly, this increase was similar for both genders. However, at late follow-up, radiologic examination disc height regressed more than twice as much in men compared to women. One can speculate about the possible causes for these discrepancies, but we have no solid explanation. The significantly increased disc height in the L3-L4 segment for men but not women is an interesting finding. However, the low number of male patients treated at L3-L4 makes these results uncertain.

The partial loss of gained disc height from postoperative until the final examination might be what could be expected in any fusion. As a similar loss of disc height takes place when patients are treated with PLIF [22], this phenomenon of "settling" is not specific only for the method to fuse described in this study. In that same study [22], PLF performed as an "in situ" fixation managed to maintain 30% of postoperative disc height increase at late follow-up. In our study, 46% of postoperative disc height was maintained. In a newly published TLIF study, Ould-Slimane et al. stated that TLIF might be superior other methods, in restoring and maintaining disc height and Lordosis [7]. This was in contrast to the results published for PLIF [22,29,46], however the study group in the TLIF study was rather small (45 patients). The PLIF and the TLIF techniques are very similar, why a major difference between them would be surprising.

Some studies suggest that PLF cannot increase, restore, or maintain disc height [16]. In the current study, disc height increased in spite of settling at the final follow-up; however, the increase was only significant in half of the treated segments.

One of the main concerns with lumbar fusion is the risk of developing secondary adjacent segment disease (ASD). The literature has been slightly contradictive on this matter, but the common opinion tends to acknowledge this phenomenon [37-44]. When the primary surgical goal with fusion is attained, segmental motion is almost reduced to zero, which is believed to reduce or relieve back pain. Physiological motion is then transferred to adjacent segments, which might accelerate DDD in those segments and give rise to ASD [41,45]. If lordosis can be restored or at least kyphosis inhibited in the treated segment, the risk of ASD can be reduced [43,44].

Loss of disc height could explain observed loss of lordosis at late follow-up [16,17], but it is somewhat peculiar that lumbar lordosis still decreased even though disc height increased at late follow-up compared to pre-operative disc height. This result challenges the correlation between loss of disc height and loss of lordosis. Other factors might affect loss of lordosis.

Previous studies have examined whether and how inter-corporal fusion methods restore segmental Lordosis [16,29,46,47]. Two of these studies have proven that using PLIF, 25%-80% of segmental lordosis is lost after surgery [29,46]. Dimar et al. concluded that PLF was the least successful of the four fusion methods with respect to restoring lordosis; PLF had a 9% loss of lordosis at the six-month follow-up [16]. This current study shows that the special technique used to perform PLF results in a mean loss of 11.75% postoperatively, which is comparable to the above data and still better than PLIF in some cases. At late follow-up (≥ 10 months), the maximum loss of segmental lordosis was 24% in L5/S1 (men), 28% in L4/L5 (women), 14% in L3/L4 (all subjects), and 16% in total lordosis for all operated segments. A somewhat higher loss of lordosis in the present study might be explained by the longer follow-up in this study compared to Dimar et al. [16]. One segment displayed an increase in segmental lordosis. This probably ensues from a combination of the pre-tensioning of the pedicle screw instrument as described and the locking of the angle between screws and rods.

Different alternatives have been tried to make measuring from plain X-ray films on anterior/posterior disc height and lordosis more exact, but without improvement in accuracy [48]. The methods we used for measuring disc height and segmental lordosis are less accurate than more advanced recently presented methods (RSA, DCRA, and CT-based Volume fusion), but this study is based on the same methods as the fusion studies we are comparing [20,22,29,46,47]. Furthermore, our measurements were made with the help of digitalized measuring tools as compared to measuring on actual films using protractors and rulers; digitalized measuring tools are the most accurate way to make measurements [14,15,31-34]. We reasoned that the accuracy used in this study would suffice in giving an overview of the results of this new form of PLF, and further need for accuracy in these issues is doubtful. All differences in disc height exceeded the ME for the method.

The period between preoperative and direct postoperative X-ray examination might have an impact on both lordosis and disc height.

With some films as old as eight years preoperative, it might be questionable whether any loss of disc height or lordosis can be seen on those X-ray films. The degeneration might certainly have progressed significantly during the period until the operation, which would mean that true preoperative disc height and lordosis was far smaller than measured values. This could mean that in some participants true increase of disc height was larger than measured increase of disc height, and true loss of lordosis was smaller than measured loss. This might also explain why direct postoperative lordosis is smaller than preoperative lordosis.

When choosing surgical method, operating time, blood loss, and postoperative days in hospital should be considered. These issues have not been specifically approached in this study, but operation time in our study seems to be shorter for PLF than in the earlier reported study (123 minutes (range 92-161) vs. 196 minutes (range 115-310)) [22]. In this study, the average blood-loss was 267 ml (range 110-470) whereas the corresponding figures for the compared study in the PLF-group was 1082 ml (range 720-2100) [22]. This was achieved due to meticulous surgery technique combined with hemostatics applied to the transplant location.

Earlier reports comparing frequencies of complications appearing after use of different fusion methods give PLF the advantage [20,21,49]. If, for example, scar formation in the spinal canal is present from previous surgery, it might appear more advantageous to perform a PLF. On the other hand, in this study, the described method of performing instrumented PLF has a definitive limitation in that it is not expected to lead to increased disc height if bone quality is too poor to allow for distraction when forces are applied to the pedicle screws. We have not studied the limits of bone quality needed to use this method. We have not been able to find reports on whether correlations exist between clinical results and an increase of disc height; this will be the focus of future work with this patient material.

Conclusion

Our results regarding increase and preservation of disc height with this special technique of performing PLF correlate close to published results after intercorporal fusions. This is why further use of this method seems acceptable. The finding of a more intact segmental lordosis than with PLIF is novel information and might favor PLF contra interbody fusions or as in the case of PLIF it might suffice with PLF without interbody fusion [43,44]. Future studies should examine whether surgically increased disc height correlates with clinical results.

References

1. Fritzell P, Hägg O, Wessberg P, Nordwall A; Swedish Lumbar Spine Study Group (2001) 2001 Volvo Award Winner in Clinical Studies: Lumbar fusion versus nonsurgical treatment for chronic low back pain: a multicenter randomized controlled trial from the Swedish Lumbar Spine Study Group. Spine (Phila Pa 1976) 26: 2521-2532.
2. Ekman P, Möller H, Hedlund R (2005) The long-term effect of posterolateral fusion in adult isthmic spondylolisthesis: a randomized controlled study. Spine J 5: 36-44.
3. SBU Report 108. Ont I ryggen – orsaker, diagnostik och behandling. SBU Rapport 108. (Pain in the back – causes, diagnosis and treatment. Reportno. 108). Stockholm, Sweden: The Swedish Council on Technology Assessment in Health Care; 1991. [Swedish version available in full-text at: www.sbu.se summary and conclusions available in English at the same web-site.]
4. SBU Report 145. Ont i ryggen, ont i nacken: En evidensbaserad kunskapssammanställning. SBU Rapport 145/1 & 2. SBU, (Back pain, neck pain: An evidens based review. Report no. 145. Stockholm: The Swedish Council on Technology Assessment in Health Care; 2000). [Swedish version available in full-text at: www.sbu.se. summary and conclusions available in English at the same web-site.]
5. Wadell G, Burton AK (2005) Concepts of rehabilitation for the management of low back pain. Best Pract Res Clin Rheumatol 19: 655-670.
6. Berg S (2011) On total disc replacement. Acta Orthop Suppl 82: 1-29.
7. Ould-Slimane M, Lenoir T, Dauzac C, Rillardon L, Hoffmann E et al. (2012) Influence of transforaminal lumbar interbody fusion procedures on spinal and pelvic parameters of sagittal balance. Eur Spine J 21: 1200-1206.
8. de Schepper EI, Damen J, van Meurs JB, Ginai AZ, Popham M, et al. (2010) The association between lumbar disc degeneration and low back pain: the influence of age, gender, and individual radiographic features. Spine (Phila Pa 1976) 35: 531-536.
9. Pye SR, Reid DM, Smith R, Adams JE, Nelson K, et al. (2004) Radiographic features of lumbar disc degeneration and self reported back pain. J Rheumatol 31: 753-758.
10. Symmons DPM, van Hemert AM, Vandenbrouke JP, et al. (1991) A longitudinal study of back pain and radiological changes in the lumbar spines of middle aged women II. Radiographic findings. Ann Rheum Dis 50: 192-196.
11. Shujie T, Xueying M (2011) Does Disc Space Height of Fused Segment Affect Adjacent Degeneration in ALIF? A Finite Element Study. Turk Neurosurg 21: 296-303.
12. Lidar Z, Behrbalk E, Regev G, Salame K, Keynan O et al. (2012) Intervertebral Disc Height Changes after Weight Reduction in Morbid Obese Patients, its Effect on Life Quality, Radicular and Low Back Pain. Spine 37: 1947-1952.
13. Djurasovic M, Carreon LY, Crawford Lii CH, et al. The influence of preoperative MRI findings on lumbar fusion clinical outcomes. Eur Spine J 2012-03-03
14. Dabbs VM, Dabbs LG (1990) Correlation between disc height narrowing and low-back pain. Spine 15: 1366-1369.
15. Pope MH, Hanley EN, Matteri RE, et al. (1977) Measurement of intervertebral disc space height. Spine 2: 282-286.
16. Dimar JR, Glassman SD, Vemuri VM, Esterberg JL, Howard JM et al. (2011) Lumbar lordosis restoration following single-level instrumented fusion comparing commonly used techniques. Orthopedics 34: 760-764.
17. Djurasovic M, Carreon LY, Glassman SD, Dimar JR 2nd, Puno RM et al. (2008) Sagittal Alignment as a Risk Factor for Adjacent Level Degeneration: A Case-Control Study. Orthopedics 31: 546.
18. Lee CK (1988) Accelerated degeneration of the segment adjacent to a lumbar fusion. Spine 13: 375-377.
19. Spivak JM, Kummer FJ, Chen D (2010) Intervertebral foramen size and volume changes in low grade, low dysplasia isthmic spondylolisthesis. Spine 15: 1829-1835.
20. Fritzell P, Hagg O, Wessberg P, Nordwall A, Swedish Lumbar Spine Study Group (2002) Chronic low back pain and fusion. A comparison of three surgical techniques: a prospective multicenter randomized study from the Swedish Lumbar Spine Study Group. Spine 27: 1131-1141.
21. Videbaek T, Christensen F, Soegaard R (2006) Circumferential Fusion Improves Outcome in Comparison With Instrumented Posterolateral Fusion: Long-term Results of a Randomized Clinical Trial. Spine 31: 2875-2880.
22. Kim KT, Lee SH, Lee YH, Bae SC, Suk KS (2006) Clinical Outcomes of 3 Fusion Methods Through the Posterior Approach in the Lumbar Spine. Spine 31: 1351-1357.
23. Van Tulder MW, Koes B, Malmivaara A (2006) Outcome of non-invasive treatment modalities on back pain: an evidence-based review. Eur Spine J 15: S64-S81.
24. Gibson JNA, Waddell G. Surgery for degenerative lumbar spondylosis. The Cochrane Database of Systematic Reviews 2005, Issue 2. Art. No: CD001352. pub2. DOI: 10.1002/14651858.CD001352.pub2.
25. Don AS, Carragee E (2008) A brief overview of evidence-informed management of chronic low back pain with surgery. Spine J 8: 258-265.
26. Chou R, Loeser JD, Owens DK, Rosenquist RW, Atlas SJ, et al. (2009) Interventional therapies, surgery, and interdisciplinary rehabilitation for low back pain: an evidence-based clinical practice guideline from the American Pain Society. Spine 34: 1066-1077.
27. Howort MB (1943) Evolution of spinal fusion. Ann Surg 117: 278-289.
28. Freeman BJ, Licina P, Mehdian SH (2000) Posterior lumbar interbody fusion combined with instrumented postero-lateral fusion: 5-year results in 60 patients. Eur Spine J 9: 42-46.

29. Gödde S, Fritsch E, Dienst M, kohn D (2003) Influence of cage geometry on sagittal alignment in instrumented posterior lumbar interbody fusion. Spine 28: 1693-1699.

30. Nehme AE, Riseborough EJ, Reed RB, et al. Normal spine growth. In *Scoliosis*. (ed. P. A. Zorab & D. Siegler), London Academic Press 1980; pp. 103-109.

31. Farfan HF (1973) Mechanical disorders of the low back. Philadelphia, Lea and Febiger, 1973, pp 37-40.

32. Tibrewal SB, Pearcy MJ (1985) Lumbar intervertebral disc heights in normal subjects and patients with disc herniation. Spine 10: 452-454.

33. Amonoo-Kuofi H.S (1991) Morphometric changes in the heights and anteroposterior diameters of the lumbar intervertebral discs with age. J Anat 175: 159-168.

34. Cobb JR (1948) Outline for the study of scoliosis. In: Thomson JEM, Blount WP, eds. American Academy of Orthopaedic Surgeons. Instructional Course Lectures. Ann Arbor: JW Edwards 5: 261-75.

35. Harrison DE, Harrison DD, Cailliet R, Janik TJ, Holland B (2001) Radiographic Analysis of Lumbar Lordosis Centroid, Cobb, TRALL, and Harrison Posterior Tangent Methods. Spine 11: 235-242.

36. Lim MR, Loder RT, Huang RC, Lyman S, Zhang K et al. (2006) Measurement error of lumbar total disc replacement range of motion. Spine 31: 291-297.

37. Axelsson P, Johnsson R, Strömqvist B (2007) Adjacent segment hypermobility after lumbar spine fusion: No association with progressive degeneration of the segment 5 years after surgery. Acta Orthop 78: 834-839.

38. Videbaek TS, Eglund N, Christensen FB, Grethe Jurik A, Bünger CE (2010) Adjacent segment degeneration after lumbar spinal fusion: the impact of anterior column support: A RCT with an eight- to thirteen-year MRI follow-up. Spine 35: 1955-1964.

39. Sears WR, Sergides IG, Kazemi N, Smith M, White GJ et al. (2011) Incidence and prevalence of surgery at segments adjacent to a previous posterior lumbar arthrodesis. Spine J 11: 11-20.

40. Schmoelz W, Huber JF, Nydegger T, Dipl-Ing, Claes L et al. (2003) Dynamic Stabilization of the lumbar spine and its effects on adjacent segments. J Spinal Disord Tech 16: 418-423.

41. Gillet P (2003) The fate of the adjacent motion segments after lumbar fusion. J Spinal Disord Tech 16: 338-345.

42. Dimitriev AE, Gill NW, Kuklo TR, Rosner MK (2008) Effect of multi level lumbar disc arthroplasty on the operative- and adjacent-level kinematics and intradiscal pressures: An in vitro human cadaveric assessment. Spine J 8: 918-925.

43. Bae JS, Lee SH, Kim JS, Jung B, Choi G (2010) Adjacent Segment Degeneration after Lumbar Interbody Fusion with Percutaneous Pedicle Screw Fixation for Adult Low-Grade Isthmic Spondylolisthesis: Minimum 3 Years of Follow-up. Neurosurgery 67: 1600-1608.

44. Min JH, Jang JS, Jung BJ, Lee HY, Choi WC et al. (2008) The Clinical Characteristics and Risk Factors for the Adjacent Segment Degeneration in Instrumented Lumbar Fusion. J Spinal Disord Tech 21: 305-309.

45. Ghiselli G, Wang JC, Bhatia NN, Hsu WK, Dawson EG (2004) Adjacent segment degeneration in the lumbar spine. J Bone Joint Surg Am 86: 1497-1503.

46. Takahashi H, Suguro T, Yokoyama Y, Iida Y, Terashima F et al. (2010) Effect of cage geometry on sagittal alignment after posterior lumbar interbody fusion for degenerative disc disease. J Orthop Surg 18: 139-142.

47. Kroppenstedt S, Gulde M, Schönmayr R (2008) Radiological Comparison of Instrumented Posterior Lumbar Interbody Fusion with One or Two Closed-Box Plasmapore Coated Titanium Cages: Follow up Studies Over More Than Seven Years. Spine 33: 2083-2088.

48. Schuler TC, Subach BR, Branch CL, Foley KT, Burkus JK et al. (2004) Segmental lumbar lordosis: manual versus computer-assisted measurement using seven different techniques. J Spinal Disord Tech 17: 372-379.

49. Christensen FB, Hansen ES, Eiskjaer SP, Høy K, Helmig P, et al. (2002) Circumferential lumbar spinal fusion with Brantigan cage versus posterolateral fusion with titanium Cotrel-Dubousset instrumentation: a prospective, randomized clinical study of 146 patients. Spine (Phila Pa 1976) 27: 2674-2683.

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