Eur Spine J (2000) 9 : 224–229

ORIGINAL ARTICLE

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Anterior lumbar interbody fusion with threaded fusion cages and autologous bone grafts

Received: 9 August 1999
Accepted: 17 November 1999

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Abstract The goal of this study was to evaluate the ability of Ray threaded fusion cages, when used in an anterior approach, to restore intervertebral height and to improve the functional and occupational performance of the patients. The present study was initiated because insertion of fusion cages through a posterior approach causes destruction of facet joints and violation of the spinal canal. The anterior approach for insertion of threaded fusion cages to accomplish lumbar interbody fusion was evaluated in a series of 13 patients suffering monosegmental disc disease. The patients' functional and occupational performance was evaluated using the Prolo score. Radiological measurements were used to evaluate disc height and degree of penetration into the endplates, and to confirm fusion. Seven of the 13 patients were short-term failures and had to be revised within 2 years. The study found that revised patients had poorer Prolo scores than non-revised patients. Although for the non-revised patients, the mean Prolo scores remained relatively stable during the 1st year, they dropped after 3 years. We were not able to identify any further clinical or radiological differences between the groups. These results indicate that although the anterior approach seems technically suitable for insertion of threaded fusion cages, destruction of the anterior longitudinal ligament and the anterior part of the annulus fibrosis appears to result in destabilisation of the motion segment.

Key words Arthrodesis · Lumbar vertebrae · Pseudoarthrosis · Spinal fusion

Introduction

When conservative treatment fails to give satisfactory results for patients with incapacitating low back pain due to monosegmental degenerative disc disease, the method of choice is monosegmental fusion. However, the long-term effect of this treatment remains unclear.

The fusion rate for non-instrumented monosegmental fusion (MSF) in the literature varies between 75% and 98%. Monosegmental anterior lumbar interbody fusion (ALIF) using autologous bone grafts has a reported failure rate of 3–25% [5, 7, 19, 20]. Monosegmental posterior interbody fusion (PLIF) using autologous grafts will fuse in 88–98% of cases [18].

A problem associated with the use of autologous bone grafts in interbody fusion is the high morbidity of the donor site [23]. Many attempts have been made to avoid the use of tricortical autologous grafts. This has resulted in the use of different materials such as bioceramics, corals, allografts, and constructs made from carbon fibre or metal. The results of fusions performed using these techniques are inconsistent and not convincing [1, 5, 9, 10].

The most popular method to achieve interbody fusion has been autologous bone grafts, but the use of instru-

mentation has increased. Brantigan developed a carbon-fibre cage for posterior application and reported fusion rates of up to 100% [1]. Stender et al. reported good results in 76% of their patients with a cobalt-chrome molybdenum implant for anterior fusion; however, the subjectively reported results for return to work and pain reduction showed good results in only 68% [17]. The Bagby and Kuslich method [8] has a fusion rate of 98% when used in an anterior approach and 100% when used in a posterior approach.

For the PLIF procedure, in 1989, Ray [15] introduced the use of hollow, cylindrical, titanium threaded fusion cages (TFCs) filled with autologous cancellous bone to treat monosegmental symptomatic disc disease without radiculopathy or spinal stenosis. In his view, the cage would restore the intervertebral disc height and the construct would be intrinsically stable because the cages are screwed into the vertebral endplate. Using slightly oversized cages, a distraction between the vertebral bodies would occur so that intervertebral height is restored. The end result would be bone ingrowth from the endplates through the fenestrations of the cages into the impacted cancellous bone. Ray advised the insertion of the TFC using a posterior approach, which could be combined with discectomy or decompression of the spinal canal. Such a treatment, however, causes extensive destruction of posterior elements (in particular the facet joints) and peridural fibrosis. In order to determine whether stabilisation of the spine could be achieved without a violation of the spinal canal, we performed a prospective clinical study in which TFCs were inserted by an anterior approach. The goal of the study was to evaluate the ability of the cages, when used in an anterior approach, to restore the intervertebral height and to promote a solid fusion. The functional and occupational performance of the patient was considered in addition to the radiological outcome.

Materials and methods

Between October 1992 and September 1993, 13 consecutive ALIF procedures using TFCs were performed by one of the authors. There were seven female and six male patients, with an average age of 35 years (range 24–43 years) at the time of surgery. The indication for surgery was monosegmental disc disease with predominant complaints of low back pain. In all cases, the pathological disc was at the L5–S1 level (as established by a discomanometry) and all the segments were symptomatic during hydraulic distension. On discography, the disc was found to be degenerative, and in 8 of the 13 cases the disc was not contained (dye leak in the epidural space). An additional discography of the adjacent disc (L4–L5) was also performed in order to exclude 'silent' pathology, i.e. disc degeneration at that level. The decision to perform a fusion was based not only on the clinical syndrome and a positive discography, but also on an immobilisation trial by a plaster cast with a thigh extension (all patients) and a percutaneous transpedicular fixation of the affected segment as described by Olerud and Hamberg [12] (in two cases). All patients reported a considerable decrease in low back pain during the trial immobilisation.

Seven of the 13 patients had previously received a discectomy (predominantly chemonucleolysis) or a laminectomy. In 12 of the 13 patients, there were complaints of pseudoradicular pain.

Operative technique

A mid-line incision was used between the umbilicus and the pubic symphysis. The lumbosacral junction was approached retroperitoneally. After excision of the intervertebral disc, the cartilage from the endplates was removed by sharp curettes. Care was taken to protect the subchondral bone, and osteotomes or chisels were never used. The beds of the cages were prepared according to the standard technique described by Ray [15]. All the preparations were performed with the vertebral bodies under maximum distraction by an AO spreader. After the size had been determined, the cages were packed with autologous cancellous bone that had been harvested from the inner part of the right iliac crest. An additional incision was needed in order to approach the iliac crest. The cancellous bone pieces were impacted by a round impactor and protruded 2–3 mm through the fenestrations of the cages. Cages with an 18-mm diameter were used in nine patients, eight of which had a length of 26 mm while one had a length of 21 mm. In three patients, cages with a diameter of 16 mm and a length of 26 mm were applied, while in one patient a cage with a diameter of 18 mm and a length of 21 mm was used. Figure 1 shows the positioning of the cages. After bed rest for 5–7 days, the patients were mobilised with a thoracolumbar spinal orthesis (TLSO), which they had to wear for 3 months after surgery.

Assessment of outcome

The patients were seen at 6 weeks and 3, 6, 12, and 36 months after surgery. At each assessment, clinical examination and X-rays were performed. The patients' functional and occupational status were evaluated using the Prolo score (see below) at all follow-ups except the first (6 weeks). At the final clinical examination, all patients were seen by an independent observer who was only involved at the end of the follow-up study.

The Prolo score

Functional capacity and occupational status were evaluated and compared using the Prolo score [14]. This score is a modification of the evaluation system proposed by Urist and Dawson [22]. On the Prolo score, patients can receive a maximum score of 5 points on the economic status, such as ability to work or maintain alternative occupation. On the functional status, patients can receive a maximum score of 5 points for intensity of pain and the influence of pain on daily activities. The evaluation for the outcome is defined by the sum of the two stated scores, as follows: 9–10 points = excellent; 7–8 points = good; 5–6 points = fair; and 2–4 points = poor.

Radiological measurements

Comparative measurements were performed on anteroposterior (AP) and lateral radiographs as well as on flexion/extension views, in order to estimate the position of the cages and the degree of restoration of the height of the intervertebral discs. Measurements on the AP radiographs, the so-called Ferguson view [21], distinguished symmetric from eccentric placement (Fig. 2). Measurements on the standard lateral view included anterior and posterior distance between the endplates as well as the degree of penetration of the cages into the vertebral bodies by measurement of the α-angle and percentage penetration into the endplate. The α-angle is

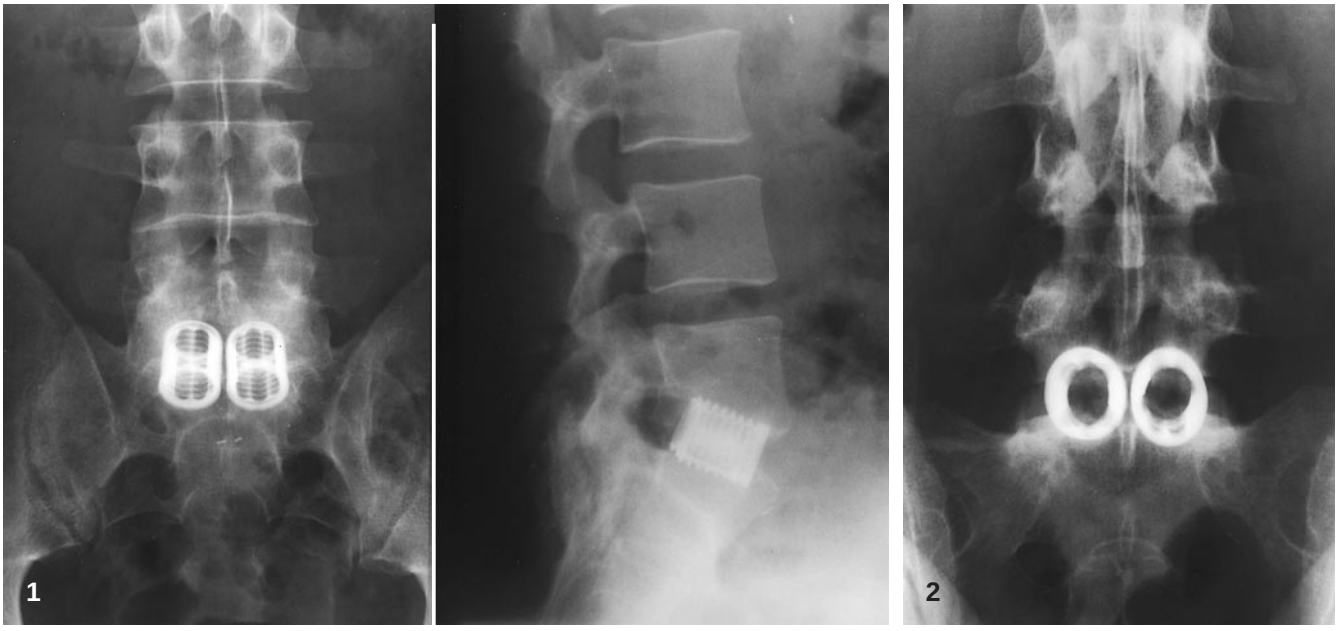

Fig. 1 Examples of the postoperative radiographs showing the positioning of the threaded fusion cages in an anterior-posterior (*left*) and lateral view

Fig. 2 Example of the Ferguson view for evaluation of symmetric versus eccentric placement of the fusion cages

measured as the angle between the cage and the L5 vertebral endplate (Fig. 3B). Since the cages have a cylindrical shape and the distracted intervertebral space in the sagittal plane has the form of a wedge, the cage is expected to penetrate the vertebral bodies to some degree, particularly in the posterior portion. Distance between the endplates (intervertebral distance) was measured as a proportion of the diameter of the disc according to Farfan's method [3, 13]. Flexion/extension radiographs were used to observe absence of motion (Fig. 3C). On these radiographs, motion segments were considered to be fused if the motion at the L5–S1 level between flexion and extension views did not exceed 2°.

Statistical analysis

Statistical analysis included a repeated measures analysis of variance and correlation. A significance level of $\alpha = 0.05$ was used. For the calculation of the failure rate, Kaplan-Meier techniques were used. The failure rate is expressed as number of failures per patient years. Paired *t*-tests were used to evaluate changes over time within groups, and normal *t*-tests were used to evaluate changes between groups. Due to small sample sizes, exact *P*-values were calculated when necessary. Ordinal and dichotomous variables were analysed with χ^2 tests.

Results

The average duration of surgery was 78 min (range 60–110 min). The average anaesthesia duration was 107 min (range 75–120 min). The average blood loss was 391 ml (range 150–850 ml). No intra-operative complications were observed. In one male patient, a transient retrograde ejaculation was noted. The average follow-up was 24 months (SD = 12.7) with a minimum of 6 months follow-up, and a maximum of 36 months follow-up. One patient was lost to follow-up after 1 year.

In 7 of the 13 patients, revision surgery was performed because of increased complaints and suspected pseudoarthrosis. A posterior approach was used for the revision

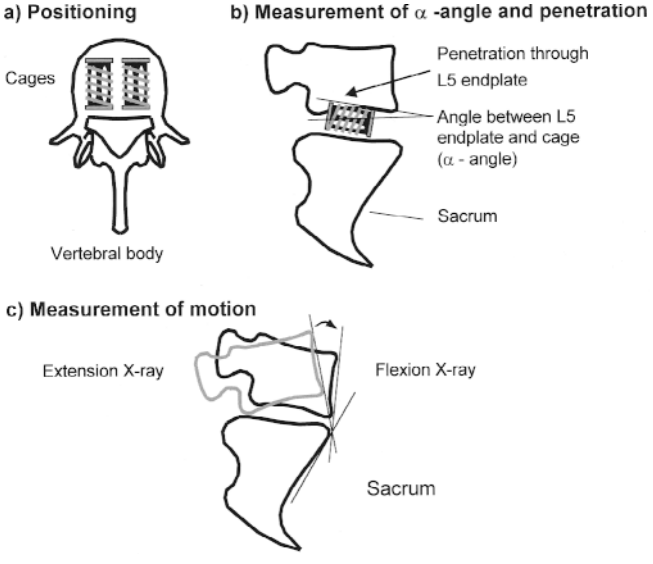

Fig. 3 **A**The position of the cages in the intervertebral disc space in a transverse section. **B,C** Measurements made on the lateral radiographs: **B** determination of the angle between the fusion cage and the L5 vertebral body α-angle); **C** determination of motion, measured as the difference in the angle between the L5 vertebral body and the sacrum on extension and flexion radiographs

Fig. 4 Example of the revision procedure for patients with increased complaints and suspected pseudoarthrosis: facet arthrodesis with translaminar screws

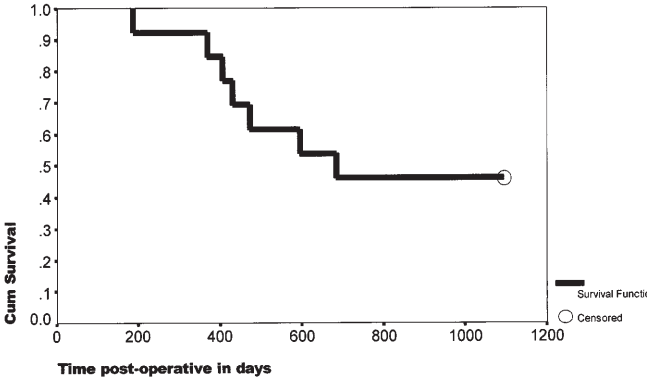

Fig. 5 Kaplan-Meier survival curve displaying the fraction of the patients not revised during the follow-up period. The study was ended at t = 1095 days (3 years)

in all seven cases, and pathological mobility was observed when putting distraction between the spinous processes of the adjacent vertebrae. To achieve stabilization, an additional facet arthrodesis by two translaminar screws was performed using the technique described by Magerl [11] (Fig. 4). No additional bone was used. A TLSO was prescribed for about 3–6 months after revision surgery. In one case, the translaminar screws broke and a further posterolateral fusion with autologous bone was added. A clinical Prolo score was obtained for these patients after revision. The average increase in the Prolo score after additional surgery was 0.43 (SD = 2.5), with a maximum increase of 5 and a maximum decrease of 2. In all revision patients, a pseudoarthrosis was confirmed peroperatively.

The revised group and the non-revised group were compared. For revision patients, the average follow-up was 17.1 months (SD = 11.2), for non-revision patients the average follow-up was 32 months (SD = 9.8). The patients who had previously received a discectomy or laminectomy were evenly divided between the group that required a revision during the trial and the group that did not. In Fig. 5, a Kaplan-Meier survival curve shows the course of revisions (failures) over time. The failure rate was 2.33 per patient year (95% CI: 1.35–4.02). After a high incidence of failures in the early period (up to 2 years), the survival rate appears to stabilise.

In the total patient group, mean preoperative disc height, as a ratio to disc diameter, was 0.23 (SD = 0.04) preoperatively. Paired t-tests show significant increase in mean disc height after 3 months to 0.33 (SD = 0.06, P = 0.000). After 6 months, the disc height is stable at 0.33 (SD = 0.04). The α-angle varies between 7° and 25°. There is a correlation between α-angle and posterior penetration of the L5 endplate (r = 0.63, P = 0.021).

The mean Prolo scores and numbers of patients per score category for the non-revised patients are shown in Table 1, those for the revised patients are given in Table 2. There is a significant difference between Prolo scores of the two groups in the period from 3 months to 1 year: $F(1,10) = 6.08$; P = 0.033. Both groups have a significant time-effect for the period of 3 months to 1 year: $F(2,20) = 9.46$; P = 0.001. There is no interaction effect between revision and course of Prolo scores over time, indicating that there is no significant difference between the two groups in the time effect on Prolo scores. Preoperative disc height and increase in disc height are not statistically

Table 1 Mean Prolo scores and distribution of the scores for the five nonrevised patients[a]

[a] One patient is omitted and referred to as 'lost to follow-up'

Prolo score	3 months	6 months	1 year	3 years
Mean score (SD)	8.20 (1.30)	8.20 (1.30)	7.20 (1.30)	6.8 (1.64)
Excellent (*n*)	3	3	0	0
Good (*n*)	1	1	4	3
Moderate (*n*)	1	1	1	2
Bad (*n*)	0	0	0	0

Table 2 Mean Prolo scores and distribution for revised patients

[a] One patient had already been revised during the first postoperative year

Prolo score	3 months (*N* = 7)	6 months (*N* = 7)	1 year (*N* = 6)[a]	After revision (*N* = 7)
Mean score (SD)	6.43 (1.51)	6.43 (1.51)	5.40 (1.14)	6.00 (1.83)
Excellent (*n*)	1	1	0	1
Good (*n*)	2	2	1	2
Moderate (*n*)	3	3	3	2
Bad (*n*)	1	1	2	2

different ($P = 0.76$) for revised (from 0.22 preoperatively to 0.33 postoperatively) and non-revised patients (from 0.25 to 0.33). Mean posterior penetration for revision patients was 24.3% (SD = 11.5) and for non-revision patients 20.5% (SD=6.5). The correlation between length of cages and need to revise (r=0.51) is not significant (P = 0.08).

Discussion

In this prospective clinical study, 13 pairs of TFCs were used in 13 consecutive patients suffering from incapacitating low back pain due to monosegmental symptomatic disc degeneration of L5-S1. The anterior retroperitoneal approach allows adequate exposure and permits access up to a 45-mm width of the intervertebral disc at level L5-S1. The operative technique was a modification of the PLIF technique described by Ray.

The outcome of the TFCs used in the ALIF procedure is disappointing. One of the 13 patients had to be revised during the 1st postoperative year and six patients during the 2nd postoperative year. Only eight of the patients had an excellent or good rating on the Prolo score at the 3-month follow-up, and this number dropped to six at the 1-year follow-up and further to three at the 3-year follow-up. The high rate of seven cases with an established pseudoarthrosis is very disturbing, and suggests a serious loss of intrinsic stability of the motion segment.

The suspected instability of the fused segments has four possible explanations. First, there is only a small contact area between the convexity of the cage and the relatively flat endplate of the vertebral body. Secondly, the discongruency between the cylindrical shape of the cage and the wedge-shaped intervertebral disc space in the sagittal plane could result in destruction of the posterior part of the L5 endplate. If so, the posterior part of the cage, which is supposed to resist a considerable amount of compressive force, will rest on the softer cancellous vertebral body bone [2, 6, 16]. The decrease of posterior intervertebral disc height during this time is a result of the subsidence of the cage into the posterior part of the vertebral body. Thirdly, the removal of the entire anterior longitudinal ligament (ALL) and more than 4-cm width of the annulus fibrosis could destabilise the motion segment considerably. The relative stability achieved by maximal distraction and by the use of oversized cages would only be temporary, and would decrease over time because of relaxation and lengthening of the ligamentous structures. Fourthly, blocking motion segments by interposition of a rigid body between the vertebrae seems to be sufficient in anteflexion and to some extent in rotation and lateroflexion. In case of severe loss of the ALL, however, the segment would permit movement and remain unstable during extension [4].

The evaluation of fusion by flexion/extension radiographs is not entirely reliable. The possibility of evaluating the 'fusion mass' by 'looking' through the cage on the AP view according to Ferguson is unreliable, and not of clinical use. Images from computed tomographic (CT) scans cannot be used because of the scattering effect of the metal. Despite some new techniques, CT scanning is still insufficient for evaluation of bone density and the level of incorporation of the cancellous bone into the cage.

Conclusion

An L5-S1 anterior lumbar interbody fusion by threaded fusion cages as a stand-alone procedure gives disappointing clinical and radiological results. Although the anterior retroperitoneal approach is suitable for insertion of threaded fusion cages for anterior lumbar interbody fusion of the lumbosacral junction, the destabilisation of the motion segment resulting from the destruction of the anterior longitudinal ligament and the anterior part of the annulus fibrosis cannot be compensated for by distraction and oversized cages. The discrepancy between shape of the cage and the shape of the intervertebral space could also contribute to the instability of the motion segment during the transfer of compressive loads.

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