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## Outcome of the Graf ligamentoplasty procedure compared with anterior lumbar interbody fusion with the Hartshill horseshoe cage

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**Abstract** The objective of our study was to assess the efficacy of Graf ligamentoplasty in comparison with rigid fixation and fusion with the Hartshill horseshoe cage for similar severity of disc degeneration. Although studies have been done on the Graf ligamentoplasty procedure and the Hartshill horseshoe cage, their efficacy has never been compared in any study. This study was done to decide whether retaining mobility and stabilizing the spine is best or stiffening the lumbar segment by fusion is preferable. Between 1995 and 1997, a prospective randomized study was performed comparing Graf ligament stabilization and anterior lumbar interbody fusion. Twenty-eight patients had single-level Graf ligaments inserted and 27 patients had single-level anterior lumbar interbody fusion (ALIF) with a Hartshill horseshoe cage and tricortical iliac crest autograft. The two groups were similar in age, sex,

symptoms, severity of the disc degeneration, and duration of follow-up. The chi-square test and *t*-test were used to evaluate the outcome. At a minimum follow-up of 2.1 years, we found that 93% of patients who had undergone Graf ligamentoplasty had a satisfactory outcome (rated “excellent” or “better”) compared to 77.8% of patients who had been treated with ALIF with Hartshill horseshoe cage stabilization and fusion, when measured on the Oswestry Disability Index ( $P < 0.05$ ). Retaining mobility in the lumbar segments gives better results after stabilisation with Graf ligaments than rigid fixation and fusion with the Hartshill horseshoe cage in the short term. We will be watching this cohort of patients over the next few years.

**Keywords** Lumbar interbody fusion · Graf ligament · Disc degeneration

### Introduction

#### Graf ligamentoplasty

The soft system stabilization of Graf provides stabilization of the lumbar spinal segments without fusion [8]. Six- or seven-millimetre titanium pedicle screws are used bilaterally, and 8-mm braided polyester bands are looped over the posteriorly projecting screws. The bands are protected from adjacent bony prominences by cylindrical diabolos and are prevented from slipping off the pedicle

screws by caps on the top of the screws. This construct constrains each motion segment in maximum extension (Fig. 1).

Abnormal rotatory movements and distraction at the facet joints associated with lumbar instability may be a cause of pain. The purpose of using a soft tissue stabilization system is to provide a firm but flexible posterior constraint to restore lumbar lordosis and stabilize the facet joints in extension [9]. Discogenic pain due to disc degeneration is thought to be a self-limiting phenomenon. Kirkaldy-Willis [16, 17] has described three stages of disc degeneration. The first stage is dysfunction. It is charac-



**Fig. 1** Radiograph showing Graf ligaments and pedicle screws

terised by circumferential and radial tears in the disc annulus and localized synovitis and hypermobility of the facet joints. The second stage is instability. There is internal disruption of the disc, progressive disc resorption, degeneration of the facet joints with capsular laxity, subluxation, and joint erosion. The final stage is stabilization. This stage comprises osteophytosis and sometimes spinal stenosis. It is assumed that the Graf ligaments will stabilize the spine in stages 1 and 2 [12, 16, 17]. These ligaments will hold the spine in normal lordosis until there is normal adaptation to the loss of disc height (the stage of stabilization) [12, 16, 17].

#### The Hartshill horseshoe cage

Fusion for lumbar disc degeneration can be performed through an anterior or posterior approach. Posterior fusion is often supplemented with instrumentation. The success rates of anterior lumbar interbody fusion (ALIF) reported in the literature are quite variable. Penta and Fraser [23] reported a 68% patient satisfaction rate and 72.4% overall fusion rate at a minimum follow-up of 10 years. Tiusanen et al. [27] used posterior external fixators for stabilisation in ALIF. Solid fusion was obtained in 71% of patients, and 74% of patients were clinically very much improved

at a minimum follow-up of 2 years (mean 5 years). Turner et al. [28] analysed 47 articles and found that on average 68% of patients had achieved a satisfactory outcome after lumbar fusion surgery (range 16–95%). Inoue and Watanabe [15] in 1982 reported on a large series of 350 patients who underwent anterior discectomy and interbody fusion for lumbar disc herniation. They achieved a 94.3% fusion rate, but the clinical results were good in 73% of patients.

Posterior fusion and instrumentation is a satisfactory method of treatment for low back pain. However, the outcome may be disappointing if the disc itself is the cause of pain. Flynn and Hoque [6], Stauffer and Coventry [26], and Newman and Grinstead [21] have reported complications of graft extrusion, compression and instability contributing to pseudarthrosis. The Hartshill horseshoe cage was designed to overcome these problems. To standardize our results to those recently reported in the literature [23, 27], we used validated objective scores and also assessed the sickness/disability benefit status and psychological distress of these patients.

The aim of our study was to evaluate the results of soft system stabilization in comparison with ALIF using Hartshill horseshoe cage for similar severity of disc degeneration.

#### Materials and methods

Forty-five patients treated for single-level disc degeneration by the senior author (N.R.B.), between April 1995 and June 1997, were included in the study. The patients were randomised to treatment with Graf ligamentoplasty ( $n=28$ ) or ALIF supplemented with Hartshill horseshoe cage ( $n=27$ ). Only patients who had discogenic back pain due to disc degeneration were included in the study; those who had disc prolapse or spinal stenosis due to disc degeneration were excluded.

Pre-operative diagnosis was made with magnetic resonance imaging (MRI) in all the patients and by provocative discography. The scans were graded from 1 to 4, using a modification of the classification proposed by Paajanen et al. [22] (Table 1). Discs appearing grey or black were classified as grade 1. Grade 2 was used to designate discs that were bulging or had annular tears. Grade 3 was used for discs that had end-plate changes, disc herniation, or less than 50% loss of disc height. Discs that had sequestered, or where there was frank intervertebral instability, or a listhesis of less than 25%, and there was greater than 50% loss of disc height but not total obliteration of the disc space were classified grade 4. Only patients with grade 3 or 4 on MRI scan were included in the study. Six patients with grade 1 and nine with grade 2 who had concordant pain on discogram were excluded from the study.

**Table 1** Classification of disc degeneration based on magnetic resonance imaging (MRI) scans (modified from Paajanen et al. [22])

Grade	Characteristic
1	Bright signal intensity, provocative discography positive
2	Intermediate signal intensity
3	Low signal intensity + annular tears
4	Disc prolapse, loss of disc height, instability, and osteophytes

**Table 2** Demographic characteristics of the two groups

	Group A (Graf)	Group B (ALIF)	P-value
Male	17	12	0.3482
Female	11	15	
Age: mean (range)	44 (26–70)	45 (25–67)	0.9888
Back pain, years: mean (range)	7.3 (0.1–32)	8.8 (2.1–32)	0.9076
Leg pain, years: mean (range)	3.9 (0–20)	7.3 (0–32)	0.7210
Disc disease grade 3 <sup>a</sup> : no. of segments	11	18	0.6645
Disc disease grade 4 <sup>a</sup> : no. of segments	17	9	0.6471
MRI grading Mean follow-up	2.5 (2.1–3.1)	2.9 (2.1–4.4)	0.9263

The patients were assigned numbers after a decision was made to operate on them. A chit was drawn blindly from a box, with Graf ligament operation designated by “1” and Hartshill horseshoe fusion designated by “2”. The draw was done a day before the operation, after which the patient was consented for the appropriate surgery. By picking up the chit from the box after shaking it well, we thought that the process was sufficiently random for there to be a 0.5 probability that the patient would have one of the two procedures.

Table 2 shows that the two groups were similar in age, sex, symptoms, grade of disc degeneration and duration of post-operative follow-up.

An independent assessor (S.M.) performed the entire review of the cases. The independent assessor was a specialist registrar, who reviewed the senior author’s results. After the full assessment and analysis, the senior author read the results and supervised the interpretation of the outcome of this study.

#### Graf ligamentoplasty (group A)

Twenty-eight patients were randomised to Graf ligamentoplasty. The operation is performed through a midline posterior approach. Intra-operative radiographs were taken to confirm the level. The facet joint capsule was preserved whilst inserting the pedicle screws. Of the 28 patients reviewed, 17 were men and 11 were women, with a mean age of 44 years (range 26–70 years). The minimum follow-up period was 2.1 years after surgery (range 2.1–3.1 years; mean 2.5 years). The mean duration of pre-operative back pain and leg pain was 7.3 years and 3.9 years respectively. Eleven levels had grade 3 involvement and 17 levels had grade 4 involvement of their discs on the MRI scan. Eight of the levels had disc bulges, and one of these showed a high-intensity zone; ten levels had annular tears. The operative site involved the level L5-S1 in 13 cases, the L4-L5 level in 14 cases, and the L3-L4 level in 1 case.

#### Hartshill horseshoe cage (group B)

Twenty-seven patients were randomised to ALIF supplemented with the Hartshill horseshoe cage. The horseshoe shape of this titanium cage permits load bearing at the periphery of the endplates. The central space is empty to accommodate the bone graft. There are oblique holes in the implant for the screw fixation to the vertebral body (Fig. 2).

The operation is performed through a direct anterior transperitoneal approach (Pfannenstiel) for L5-S1 and a standard anterolateral retroperitoneal approach for the other lumbar levels. Steinmann pins are inserted in the vertebral body and intra-operative radiographs are taken to confirm the level. The annulus is exposed and excised along with the nucleus pulposus right down to the posterior longitudinal ligament. The upper and lower endplates are cleared of all the cartilage up to the bleeding cancellous bone. A peripheral cortical rim is retained over the upper and lower surface of the adjacent vertebrae to seat the horseshoe cage. Tricortical il-



**Fig. 2** Hartshill horseshoe cage in the disc space with screws in the vertebral bodies stabilising the lumbar segment

iac crest bone autograft was used for fusion along with small pieces of cancellous graft packed firmly in the horseshoe.

Of the 27 patients reviewed, 12 were men and 15 were women, with a mean age of 45 years (range 25–67 years). The minimum follow-up period was 2.1 years after surgery (range 2.1–4.4 years; mean 2.9 years). Eighteen patients had grade 3 involvement and nine patients had grade 4 involvement of their discs. Five patients had complete annular tears. The mean duration of pre-operative back pain and leg pain was 8.8 years and 7.3 years respectively. The fusion site involved the L5-S1 level in 13 cases, the L4-L5 level in 13 cases, and the L3-L4 level in 1 case.

#### Outcome assessment

Outcome was assessed according to a variety of measures of pain and function. Pre- and post-operative scores were available for all patients.

**Fig. 3** “Core set” of outcome measures for low back pain research [4] (note: most of these items are included in the AAOS Lumbar Cluster, the Low Back Pain TyPE, and the NASS Low Back Outcome instrument)

**PATIENT OUTCOMES** (note: most of these items are included in the AAOS Lumbar Cluster, the Low Back Pain TyPE, and the NASS low back Outcome instrument)

1. During the past week, how bothersome each of the following symptoms been?

	Not at all bothersome	Slightly bothersome	Moderately bothersome	Very bothersome	Extremely bothersome
a. Low back pain	1	2	3	4	5
b. Leg pain (sciatica)	1	2	3	4	5

2. During the past week, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all [2]     A little bit [4]     Moderately [6]     Quite a bit [8]     Extremely [10]

3. If you had to spend the rest of your life with the symptoms you have right now, how would you feel about it?

Very dissatisfied [10]     Somewhat dissatisfied [8]     Neither satisfied nor dissatisfied [6]     Somewhat satisfied [4]     Very satisfied [2]

4. During the past 4 weeks, about how many days did you cut down on the things you usually do for more than half the day because of back pain or leg pain (sciatica)?

----- Number of days (0-5 days: [1]; 6-10 days: [2]; 11-15 days: [3]; 16-20 days: [4]; >= 21 days: [5])

5. During the past 4 weeks, how many days did low back pain or leg pain (sciatica) keep you from going to work or school? ----- Number of days (0-5 days: [1]; 6-10 days: [2]; 11-15 days: [3]; 16-20 days: [4]; >= 21 days: [5])

6. Over the course of treatment for your low back pain or leg pain (sciatica), how satisfied were you with your overall medical care?

Very dissatisfied [10]     Somewhat dissatisfied [8]     Neither satisfied nor dissatisfied [6]     Somewhat satisfied [4]     Very satisfied [2]

Note: The numbers in the brackets [ ] are the points. Minimum points are 10 and maximum are 50.

*Oswestry Disability Questionnaire*

Objective assessment was made by using the Oswestry Disability Questionnaire [5]. Patients were rated on the following parameters:

1. Excellent: improvement of at least 40 points and/or post-op score <20 on Oswestry Disability Index (ODI) and back to normal ODI function
2. Better: improvement of between 20 and 40 points, and/or score of between 20 and 40 on the ODI, and back to 50% of normal ODI function
3. Same: improvement of <20 points on the ODI and no functional recovery
4. Worse: post-op score worse than pre-op score on the ODI and poor ODI function after operation

*Subjective rating of pain and function*

Patients were asked to complete a ten-point visual analogue pain scale, with 0 indicating “no pain at all” and 10 indicating “maximum pain possible”. A pain drawing was used for the patients to show the site of pain. They were asked to describe the characteristic of the pain, which was scored as: numbness 4, pin prick 3, burning 2, stabbing 1. Patients’ pain and function were also evaluated using a “core set” of six questions as proposed by Deyo et al. [4]. This questionnaire covered the domains of pain symptoms, back-related function, generic well-being, disability (social role), and satisfaction with care (Fig. 3). The minimum score was 10 and the maximum 50. A post-operative score of ≤30 was considered to be a good overall outcome.

### Psychological distress

A psychometric measure incorporating the Modified Somatic Perception Questionnaire (MSPQ) [20] and the Zung Depression Scale (ZDS) [29] was used to assess psychological distress at review. A combined score from 0 to 99 is calculated and distress is defined as a score of 29 or more for men and 33 or more for women.

### Statistical analysis

The differences observed between the groups were analysed using the chi-square test and *t*-test.

## Results

### Clinical results

#### Graf ligamentoplasty

The pre-operative mean Oswestry Disability Score was 66 points (range 34–88 points) and the post-operative mean score was 25.3 (range 0–76 points). Twenty-six patients 93% improved significantly (rated as “excellent” or “better”) when measured with the Oswestry Disability Questionnaire. The pain and function results derived from the pre-operative and post-operative Oswestry Disability Questionnaire are shown in Table 3. The pre-operative “core set” mean score of 37.53 (range 18–50) improved significantly to a mean score of 20.25 (range 9–44). Twenty-two patients (78.6%) had improved significantly (score  $\leq 30$ ) as measured by the “core set” score. The improvements in the psychological distress, visual analogue pain scale, “core set” and pain drawing score were statistically significant ( $P < 0.05$ ).

**Table 3** Pre-operative and post-operative scores at last follow-up (ZDS+MSPQ Zung Depression Scale + Modified Somatic Perception Questionnaire, ALIF anterior lumbar interbody fusion)

	Group A (Graf) Mean (range)	Group B (ALIF) Mean (range)
Pre-op. Oswestry	66 (34–88)	60.22 (34–86)
Post-op. Oswestry	25.3 (0–76)	33.3 (0–82)
Pre-op. function <sup>a</sup>	16.25 (0–30)	16.48 (5–40)
Post-op. function <sup>a</sup>	56.43 (5–90)	42.96 (5–75)
Pre-op. ZDS+MSPQ	48.2 (18–75)	46.03 (18–75)
Post-op. ZDS+MSPQ	22 (0–71)	31.07 (6–99)
Pre-op. pain drawing	7.5 (1–15)	8.55 (2–30)
Post-op. pain drawing	4.5 (0–15)	5.6 (0–36)
Pre-op. visual analogue	8.4 (2–10)	8.33 (4–10)
Post-op. visual analogue	3.1 (0–10)	4.04 (0–10)
Pre-op. “core set”	37.53 (18–50)	37.52 (20–50)
Post-op. “core set”	20.25 (9–44)	22.96 (8–50)

<sup>a</sup> As measured by the Oswestry Disability Questionnaire

### Hartshill horseshoe cage

The pre-operative mean Oswestry Disability Score was 60.2 points (range 34–86 points) and the post-operative mean score was 33.3 (range 0–82 points). Twenty-one patients (77.8%) improved significantly when measured with the Oswestry Disability Questionnaire. The pain and function results derived from the pre-operative and post-operative Oswestry Disability Questionnaire are shown in Table 3. The pre-operative “core set” mean score of 37.52 (range 20–50) improved significantly to a mean score of 22.96 (range 8–50). Twenty-two patients (81.5%) had improved significantly (score  $\leq 30$ ) as measured by the “core set” score.

The improvements in the psychological distress, visual analogue pain scale, “core set” and pain drawing score were statistically significant ( $P < 0.05$ ).

### Comparison of the outcome of the two procedures

Table 3 shows the scores of the two groups on a range of measurements. Table 4 shows the outcome of patients in each group according to their rating on the ODI. There was a statistically significant difference between the two groups, with the Graf ligamentoplasty patients doing better than patients who had fusion.

### Complications

In the Graf ligamentoplasty group (group A), one patient had superficial wound infection and one had chest infection. Both settled with oral antibiotics.

In the ALIF with Hartshill horseshoe cage group (group B), there was one misplaced horseshoe that caused radicular symptoms. The patient required a revision after a fortnight. In addition there was one patient with a urinary tract infection and another with iliac bone graft donor site persistent pain.

**Table 4** Comparison of the outcome of the two groups. The outcome of the Graf ligamentoplasty group was statistically significantly better than that of the ALIF with Hartshill horseshoe cage group ( $P = 0.0477$ ; chi-square test)

	Group A (Graf)	Group B (ALIF)
Worse	2	1
Same	0	5
Better	10	4
Excellent	16	17

## Fusion

Plain radiographs were available for review. At minimum follow-up of 2.1 years, the Hartshill horseshoe cage was well seated. The patients who did not improve or were worse after the operation underwent a technetium radioisotope bone scan and flexion-extension radiographs for evidence of pseudarthrosis. MRI and computed tomographic (CT) scans were used in the early part of the study to delineate fusion and graft status, but the signal artefacts obscured the fusion site. There was no abnormal mobility at the implant vertebral body interface and the bone scans were normal for the patients who had persistent post-operative symptoms. It is possible that a few of the bone grafts may not have fused in the patients who have shown clinical improvement. These patients did not have bone scan and flexion-extension radiographs, as they had shown clinical and statistically significant improvement. Therefore, the true fusion rate in our series is not known.

## Discussion

Graf reported his initial results in 120 patients. According to his assessment, 80% were "positively satisfied" and 20% were "passable or mediocre". There was no objective assessment of the patients [8]. Grevitt et al. [10] reported on 50 consecutive patients with a minimum follow-up of 19 months, who had symptomatic degenerative disc disease. The pre-operative Oswestry score of 59% improved to 31%. Their clinical results were classified as "excellent" or "good" in 72% of patients, "fair" in 10%, "the same" in 16% and "worse" in 2%.

Graf recommended this procedure for instability associated with disc disease. Although we did not perform pre-operative stress radiographs to demonstrate overt instability, those patients who had grade 3 or 4 disc degeneration on MRI in our series probably had an element of instability [17].

Guigui and Chopin [11] evaluated the results of Graf ligamentoplasty in patients who underwent decompression after lumbar spinal stenosis. They studied 26 patients with a mean follow-up of 29 months. These patients had pre-operative and post-operative stress radiographs to measure the instability. The results were objectively scored. They found 27% of patients were unstable after the operation. They therefore concluded that soft system stabilization with neural decompression did not improve the results. In our study, we excluded patients who needed decompression, to decrease confounding variables. This was done to eliminate patients with radicular rather than discogenic problems. This made the two groups comparable in this aspect. Brechbuhler et al. [2] reported their results at a mean follow-up of 50 months. They recommended Graf ligamentoplasty for patients with no or only mild facet joint arthritis and minor disc degeneration. This

was contrary to our findings. We found a 93% (Oswestry Index) improvement in our group of patients with moderate to severe disc degeneration, who had Graf ligaments.

There are many articles in the literature concerning anterior lumbar interbody fusion that estimate the results according to fusion rate and clinical success [1, 3, 13, 14, 15, 18, 21, 24, 25, 26, 28]. An improvement of 77.8% (Oswestry Index) for anterior lumbar interbody fusion supplemented with the Hartshill horseshoe cage is a better result than was achieved in several of the series reported in literature [1, 3, 15, 23, 25, 26, 27]. The clinical success rate in these studies was at best 74% subjective and 68% objective improvement. Harmon [13, 14] reported a 93% clinical success rate. However, his patients who underwent anterior fusion had acute disc prolapse. Our improved results are probably attributable to the immediate stabilisation achieved by the horseshoe cage. The cage also prevents the graft sinkage through the vertebral endplates, prevents graft extrusion, opens up the neural foramina and recreates the normal lordosis of the lumbar segment (Fig. 2).

The disadvantage of this cage is that, because it is made of titanium, it prevents radiographic assessment of fusion. Penta and Fraser [23] and Tiusanen et al. [27] have reported that pseudarthrosis did not affect their outcome. There were several patients who had pseudarthrosis but had clinical success in their series. This may suggest that fusion may not be as important as previously thought. It may be that, by regaining the disc height, the biomechanics of the facet joints and posterior ligaments is restored to near normal tension. A nonunion anteriorly will perhaps consist of firm fibrous union, probably 1 or 2 mm thick, which would allow very limited movement under a compressive load. Therefore, a nonunion anteriorly may still abolish disc space movement to a sufficient degree to relieve pain. This may explain the clinical success in the presence of pseudarthrosis. Penta and Fraser [23] also reported in their 10-year minimum follow-up that some of the patients who had pseudarthrosis at 2 years went on to a solid fusion later. This has also been observed by Leong et al. [19]. Therefore, with no clinical evidence of implant loosening in our series, one could hope for the pseudarthrosis rate to be lower with a long enough follow-up. The Hartshill horseshoe implant should fail eventually if there is pseudarthrosis, if the theory of a race between union and implant failure is true. However, we have not had a single failure so far. One can speculate that the horseshoe is subjected to compression forces and therefore may not fail as soon as the other implants that are fixed in tension. If that is the case then the implant may create a protected, conducive environment for a prolonged period for graft incorporation. Tiusanen et al. [27] and Stauffer and Coventry [26] have recommended anterior interbody fusion as a salvage procedure. Our results show that this procedure is a suitable primary procedure.

The patients who had Graf ligaments inserted did better than those who had ALIF with the cage, at a mean follow up of 30 months. Graf ligament keeps the lumbar segments mobile. Lumbar spine may not tolerate rigid fixation very well. This may be the reason that Graf ligaments have shown better outcome. Contrary to the recommendations of Brechbuhler et al. [2], we found that Graf ligaments were successful in alleviating the symptoms even in advanced stages of disc degeneration.

Our results have been somewhat better than those reported in other series [11, 12]. We were very cautious in the patient selection for our study. Patients with radicular pain were excluded. We used MRI and provocative discography in all our patients. Guigui and Chopin [11] had only three patients who underwent pre-operative MRI before Graf ligamentoplasty, and therefore the source of non-radicular pain was not known. This could perhaps be the reason of poor outcome in their series. In our study, patients with Graf ligamentoplasty did better than those reported by Hadlow et al. [12]. Their patients were not randomised into the two groups, but were given a choice of the operation. They also reported a higher incidence of depression with greater disability in the patients who received Graf stabilisation than those who received lumbar fusion. These could be confounding factors that could have led to a poor outcome in their series of patients who had Graf ligament stabilisation.

Gardner et al. [7] have reported that the prime indication for the Graf technique is mild to moderate degenerative disc disease that is highly symptomatic, with chronic back pain punctuated by acute and disabling episodes, which they called "the lumbar instability syndrome". They stated that Graf ligamentoplasty is generally not appropriate for advanced disc degeneration. Patients who had total loss of disc height and greater than 25% sublux-

ation were excluded from the study. Perhaps we would define such degenerative changes as too advanced for soft tissue stabilisation. This was important, because we wanted to define the true role of Graf ligament stabilisation in low back surgery. We were somewhat surprised that some patients whose disc degeneration would perhaps be classified as "severe" by others [7] did well with stabilisation. There is perhaps a time when the instability becomes too advanced, and the collapse of the disc space so severe that the facet joints and the posterior spinal ligaments and muscles decompensate to such an extent that any soft system stabilisation would fail. We think that with the present investigation protocol, this stage is difficult to define. Perhaps we were lucky to have caught a few of those patients with severe disc degeneration who were not totally decompensated. The precise stage and extent of symptomatic disc degeneration that would not benefit from soft system stabilisation is yet to be defined. Perhaps future research could shed more light on this difficult problem. All our patients underwent MRI and provocative discography to produce a typical pattern of concordant pain. This group of patients was not severely depressed or disabled, nor did it have chronic behaviour pattern, which can often affect outcome in low back surgery.

Our results are short term, and it would be interesting to know whether this advantage is maintained at a mean follow-up of 5 years. With the caveat that the number of patients is small and the follow-up short, this study shows that stabilisation by Graf ligaments could have advantages over lumbar fusion. Therefore, it will be interesting to observe this cohort of patients in future.

Thus, one may recommend the Graf ligamentoplasty procedure over ALIF with Hartshill horseshoe cage for degenerative disc disease. It is a worthwhile procedure for disc degeneration in the short term.

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