Eur Spine J (2002) 11 (Suppl. 2) : S198–S205
DOI 10.1007/s00586-002-0422-x

REVIEW

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Rationale, principles and experimental evaluation of the concept of soft stabilization

Received: 8 March 2002
Accepted: 21 March 2002
Published online: 4 June 2002

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Abstract The apparent clinical success of spinal stabilization methods that restrict rather than abolish movement in relieving mechanical back pain indicates that the concept of the aetiology of back pain should be reviewed. Further understanding of how degeneration affects disc biomechanics, and an understanding of how current soft stabilization systems alters them, may allow us to define more precisely what are the essential requirements of an ideal soft stabilization system. It appears that abnormal patterns of loading rather than abnormal movement are the reason that disc degeneration causes back pain in some patients. Abnormal load transmission is the principal cause of pain in osteoarthritic joints, and both osteotomy and, indeed, joint replacement succeed because they alter the load transmission across the joint. This concept is supported by the fact that abnormal patterns of stress distribution measured across the disc correlate with painful discs on discography. Clinically, it is often noted that back pain is primarily related to position or posture, rather than movement of the lumbar spine. Clinical success after solid fusion is unpredictable because it does not necessarily prevent painful loading across the disc, and also it may interfere with maintenance of sagittal balance in varying postures. The Graf ligament restricted flexion, and was modestly successful. It unfortunately increased the load over the posterior annulus. The Dynesys system reduces movement both in flexion and extension, and appears to be more successful. However, often it also unloads the disc to a degree that is unpredictable. The authors believe that this unloading of the disc is an important feature of a flexible stabilization system. A new a design of a flexible stabilization system has recently been described in an in vitro study, which unloads the disc by introduction of a load-sharing fulcrum near the axis of movement together with an elastic posterior ligament. This design produces maximal unloading of the disc, whilst allowing a restricted range of movement, which serves the important purpose of allowing the patient to maintain sagittal balance in varying postures.

Keywords Soft stabilization · Disc degeneration · Low-back pain

Back pain: movement or load related?

It is difficult to find any basis for the concept of instability as a cause of low back pain. It was a phrase that came into use in the middle of the last century, and was used by clinicians to imply that there was some non-specific mechanical failure of the spine, as opposed to an arthritis or infection. When bioengineers became involved in trying to sort out the biomechanics of the spine [5], they embraced the term. They interpreted instability in a purely literal bioengineering sense, validated to some extent in other joints like the knee and shoulder. Thus, despite the pioneering work of Nachemson and Schultz [27], who demonstrated that pain was related to disc pressures and posture, but not movement, the era of back pain being due to a disorder called "instability" was born, and fusion was seen as the appropriate solution.

Role of the disc

It is generally recognized that morphological changes in the disc play a major role in low-back pain, although it is also recognized that there is no correlation between the degree of degeneration and the severity of back pain. The disc has two biomechanical roles, it must transmit load and it must allow a controlled range of movement, so that such movement does not compromise the adjacent neural elements. It is generally accepted that the effect of disc degeneration is to reduce movement [6, 7], not to increase it, as the term "instability" would imply.

It may be argued that, unfortunately, this reduction of movement is associated with abnormal patterns of movement, and this is the meaning of "instability". However, despite considerable efforts over many years, using flexion/extension films, no clear relationship has been established between pain and such abnormal movements. In other words, patients with degenerative disc disease may exhibit abnormal patterns of movement, yet have no pain. The one new movement that may be present in some patients with degenerative disc disease is translational movement [6, 7], as is seen in patients with degenerative spondylolisthesis. It is this movement that is often regarded as an important abnormality in patients with so called instability. In the lumbar spine such translational movement can only occur if the facet joints become incompetent, but this is not a feature in many patients with back pain. It is a common clinical experience that at re-exploration after failed posterior fusion, even if there is demonstrable flexion-extension movement and a clear pseudoarthrosis, translation movement is very seldom present.

The second role of the disc is that it must transmit load. It is well designed for this purpose. The normal disc is isotropic [12], that is to say that it behaves liked a fluid-filled bag, and transmits load uniformly across the surface of the disc and to the endplate [16, 17]. This has a number of important biomechanical consequences.

Key among these is that in any position of the spine, be it flexion, extension or lateral-bending, the load is transmitted uniformly over the endplates. There is no high spot-loading related to different positions of the spine. It may be recalled that this is the case in a normal diathrodial joint. Here, the design of the joint ensures an even pattern of load transmission. Disturbance of anatomy of the joint, such as a menisectomy in the knee, or destruction of the cartilage by disease (infection/arthritis) in other joints, leads to a disturbance in the normal weight transmission, producing pain. It was recognized many years ago that an appropriately planned osteotomy, which altered the load transmission, might result in pain relief. We are all familiar with radiographs showing the high spot-loading in a subluxing hip, and are also aware that an appropriate osteotomy, which reduces spot-loading by containing the hip, relieved pain. Similarly, in a varus or valgus deformity of knee joint, abnormal distribution of load may lead to unicompartmental osteoarthritis, and an appropriate osteotomy, especially if done early with minimal cartilage loss, would produce a satisfactory long-term result. We emphasize that the biomechanical effect was to alter the loading pattern, and the resultant clinical effect was pain relief. If we accept that in load-bearing joints overall an altered loading pattern produces pain, then we can more easily accept this concept also applies to the disc.

Another important consequence of the uniformity of distribution of load transmission across the surface of the disc is that it transmits load to the annulus, producing a tension in the annulus, and converting it into a load-bearing structure. It is established that disc degeneration alters the isotropic nature of the disc [13, 17] and, as a consequence, load transmission over the endplate becomes irregular, leading to high spot-loading, particularly associated with certain positions.

The concept of load-related pain and its clinical significance

It is curious that instability or movement abnormalities are blamed for back pain. Whenever a history is taken of chronic back pain, it is clear that the problems experienced are postural, rather than related to the process of movement. It is pain whilst bent down, it is pain whilst leaning forward, and it is pain whilst sitting. As the loads on the back are mostly produced by muscle action rather than body weight, activities that involve strong muscle action, such as lifting, are associated with pain. Standing perfectly still with a heavy load is a painful experience for some patients with a painful back, quite unrelated to any movement. We are all aware that lying down flat and reducing the load relieves pain. Nachemson [22], in his classic work, showed very clearly the close relationship of posture and load in the disc, and later Schultz and Nachemson and their co-workers [27] demonstrated the important effects of muscle action on these loads.

Exercise and physiotherapy

When we consider the use of physiotherapy in the treatment of chronic back pain, there is again a curious illogicality in our concept of how it might work. If instability were indeed the cause of chronic back pain, then the use of corsets, much used in the past, would not now be derided. If one is going to treat an unstable joint by encouraging movement, then one has to be confident that the movement one encourages is the normal pattern, and not the abnormal one. As we are not clear what abnormal patterns we are planning to prevent, it is not truly possible to plan a treatment that will specifically allow normal movement, and stop the abnormal ones. Let us suppose that it is the translation movement that we are concerned about. It is difficult to conceive that strengthening muscles, most of which are at right angles to the line of translational movement, will have any effect. But of course physiotherapy, rehabilitation and manipulation do succeed in alleviating back pain [31], presumably not by stopping abnormal movement, but by altering the loading pattern of the degenerated disc. How they might do so becomes clearer if we look more closely at the anatomy of the degenerate disc, and the effect of the altered anatomy on the biomechanical functioning.

Macro- and micro-anatomy of disc degeneration

In a clinicopathologic study on degenerated disc tissue collected from surgery and from cadaveric spines, Moore and Vernon-Roberts et al. [21] described:

> Nuclear desiccation and fragmentation leads to the eventual formation of clefts in the annulus, followed by the extrusion of mainly nuclear material through these preexisting annular clefts. Isolated fragments of annulus and endplate are much less common than nucleus in extruded material and probably also originate as part of the degenerative process.

Normal nucleus consists of a homogeneous gel of collagen and proteoglycan. In a degenerated disc, it changes to a non-homogeneous mixture of fragmented and condensed collagen, areas of fluid, and indeed areas of gas on occasion. If the load is transmitted through such a fragment within the degenerated disc, it will lead to a high focal load being transmitted to the endplate cartilage and the subchondral bony trabeculae. This results in corresponding endplate changes, apoptosis of cells and destruction and thinning of the cartilaginous endplate [2, 30].

As the nucleus become desiccated and depressurized, an increasingly larger load is transmitted through the annulus. Now the area of the disc through which most of the load is transmitted depends on the posture: in flexion the anterior annulus, in extension the posterior annulus. Loading the annulus, unprotected by the supporting pressure of the nucleus, will lead to splitting and inward folding of the annulus. This altered pattern of load transmission leads to changes in the cancellous bone architecture in the vertebral body. In a study on cadaver degenerated disc, Simpson et al. [30] observed significant architectural changes in the anterior regions of the vertebral body, with increases in the number and thickness of bony trabeculae. Minimal alterations were found at posterior regions. Bone loss was observed in central regions (most distant from the cortex) as disc disorganization increased, a reduction in both number and thickness of trabeculae. They concluded that this might be a response to a redistribution of load to the vertebral body periphery as a result of disc disorganization. What is clear is that the loading pattern is immensely variable, and that physical movement and position will alter this.

Clinical experience in support of abnormal loading as a cause of pain

An acute attack of sciatica due to disc herniation is often preceded by recurrent episodes of ‘lumbago’, lasting for a few days or longer. Often these patients are relatively asymptomatic between the episodes. When such cases are treated with discectomy to relieve sciatica, discrete fragments of disc materials are removed at operation, and this relieves sciatica, as well as the episodes of lumbago.

This well-observed clinical scenario may be explained by the experimental work reported by Brinckmann and Porter [4]. They produced models of incomplete radial tears in cadaver discs. In addition, fragmented tissue pieces that resembled those retrieved at surgery for prolapse were created in the centre of the disc. They could reproduce disc protrusion by loading such a model within physiological range when the fragment was present, but not without a fragment. They concluded that disc protrusion had to be preceded by generation of radial fissures and tissue fragmentation within the disc, and that prolapse was a late event during the course of a long-term degenerative process. In the clinical scenario alluded to, it seems probable that the fragment is present prior to the protrusion for some time. As its removal commonly cures the recurrent attacks of lumbago, is it not likely that such attacks are related to the fragment? Is it not likely that its presence, mobile in the disc space, causes on occasion an abnormal loading pattern?

Another clinical observation is the undoubted effect that manipulation can have in acute episodes of lumbago. It seems most likely that this must be related to a movement of tissues within the disc, suggesting that the internal morphology can be acutely altered. The best analogy for the discomfort is the “stone in the shoe” concept. As the stone moves to a position of lesser weight bearing area under the foot, one can walk comfortably again.

The “stone in the shoe” hypothesis – a degenerated disc is painful only at abnormal load transmission

The random nature of recurrent lumbago is difficult to tie in with a concept of instability. How would one explain relatively symptom-free periods between the episodes of acute disabling back pain on the basis of instability? Does it suddenly become stable? However, if we accept the "stone in the shoe" analogy, then the randomness and indeed the variable response to manipulation becomes explicable. By altering the distribution of fluid/fragments within the disc, one may alter the way it transmits load, and pain goes.

The concept that the actual arrangement of tissues in the disc affects load transmission also explains the fact that there is no clear correlation between degree of disc degeneration and pain.

With advanced degeneration the disc tissues become progressively more collagenized, and homogeneous, so that once again loading becomes even over this homogeneous mass, leading to spontaneous relief of pain.

Experimental work in support of the hypothesis – pressure profile across the disc and pain in discography

Although some doubt has been cast on the value of discography in identifying a painful disc, it is a common practice to perform a discogram prior to spinal fusion. This provided us with the opportunity to examine the loading patterns of degenerate discs, prior to spinal surgery [18]. Fifteen patients who were candidates for spinal fusion, and were having discograms to determine the segmental level to be fused, had a pressure profilometry study, as described by McNally and Adams [17], at the same time. In this technique, a stress transducer, mounted on a needle, is drawn through the disc so that a graph of stress against position within the disc can be plotted. Stress is a complex mechanical parameter that can vary with the direction of measurement (horizontal or vertical), the directional dependence resulting from the mechanical properties of the disc. In a normal disc, which is isotropic, the stress is the same in both directions, but in a degenerated disc, which is anisotropic, stresses vary both in their direction and across different parts of the disc. The plot of stress against position is termed a "stress profile" of the disc. All the 31discs studied were abnormal on MRI, but some were painful on discography, and others were not. It was found that the discs painful on discography had particular patterns of stress profile. The nucleus was depressurized and was not taking load. The posterior annulus was taking increased load. A number of painful discs had a very high level of focal loading in the disc. A painful disc could be predicted by an abnormal annulus in 90% of levels (P<0.001). Pain was predicted by a depressurized nucleus in 63% of levels (P<0.017). There was extensive variability of stress distribution (and therefore the mechanical function of the different areas of the disc) even in discs showing the same degree of radiographic degeneration. This demonstrated that the radiographic or MRI appearance of a disc is not a direct indicator of its mechanical competence, and fits in with the clinical observation that degree of disc degeneration is not related to pain.

This study showed that pattern of loading, rather than absolute levels of loading, was related to pain in a degenerated disc. Clearly, if this was the case, then surgery that alters loading patterns alone, without significant reduction of movement, may be an appropriate alternative to fusion.

Results of fusion

If indeed instability was the main cause of back pain, one would have expected that spinal fusion would be more successful than it has been. Improvement in the instrumentation technique resulted in increase in successful fusion rate, but this has not been reflected by a corresponding increase in the rate of successful clinical outcome [3]. Despite the introduction of pedicle screws in the late 1980s, and cages in the late 1990s, and the frequent use of circumferential fusion in association with cages, the clinical efficacy of fusion has remained the same. Indeed with more recent sophisticated methods of assessing clinical success, the so-called "excellent" results of fusion are in the region of 30% [8]!

Sagittal balance and fusion

It will be appreciated that a fusion may well produce a normal loading pattern. This may explain the successful clinical outcome in some cases. It may also be possible that a successful fusion may interfere with normal sagittal balance, especially if it involves more than one level, and may force a person to assume a position that produces abnormal load on an adjacent segment. Lazennec et al. [14] observed that a common complaint of fusion patients is that they get sitting pain. When one looks at the sitting lateral radiographs of the lumbo-sacral spine and observes the posture that is adopted, it is often seen that, if a patient has a stiff segment from L4 to S1 fusion, sitting imposes considerable postural stresses on levels above the fusion and also on the limited rotatory capacity of the sacroiliac joint, which forces both joints to their extreme limits.

Clearly a posterior fusion does not stop loading on the disc. It will reduce it and may alter its pattern. It may at the same time prevent the spine taking up a position where normal loading pattern occurs. However, in any particular patient, we are commonly not aware of the precise loading pattern and in what position it occurs, so the effect of fusing a spine in one position will be somewhat random as regards clinical success. We may fuse it in a position where the remaining loading on the disc may indeed be a painful loading position! This may explain an unsuccessful clinical outcome after a successful fusion.

One would anticipate that an anterior fusion would be more likely to produce a normal loading pattern, and indeed the results of anterior fusion are better than those of posterior fusion, which still allows endplate loading [26, 34]. However, experience with cages produces some indication as to why anterior fusion is not necessarily successful.

McAfee, in his extensive review of the results of cage fusion [15], indicated that the clinical results were little better than those of other methods of fusion, and Whitecloud et al. [33] demonstrated that, even after a circumferential fusion using cages, the rate of excellent results was only 30%. Agazzi et al. [1] reported that, again using cages, the rate of excellent or good results was only 39%, and there was no relation between clinical outcome and the success of the fusion.

Of course, with an anterior fusion with a cage, body load has to be taken by the cage and transmitted to the vertebrae below. Many of the cages had a small "footprint", and essentially loaded through the soft cancellous bone at the centre of the vertebrae, over a limited area only. Polikeit and Nolte [24] showed that the enormous loads thus produced may amount to some 500% higher than the endplate would normally experience. McAfee [15] had pointed out that clinical success was associated with the development of bone around the cage, inevitably increasing the area for load transmission and reducing the contrast between an area loaded, and one not loaded. Clearly, the clinical results of cage fusion will be improved if the cage and adjacent bone does indeed transmit load over a wide area onto the vertebrae below.

If we accept that stopping movement is not a factor in clinical success, but creating a normal loading pattern is, then we are empowered to look at other methods of changing loading patterns, without the disadvantages of producing a stiff segment.

Where is the pain arising from?

We initially thought that an abnormal loading pattern over the endplate, which is highly innervated (much more so than the disc), was the explanation of the pain. However, recent work with vertebroplasty for osteoporotic fractures demonstrates that bone itself is a source of pain, and this pain can be alleviated if the internal mechanics of the bone are strengthened by cement, without any correction of deformity. Bone is very sensitive to pressure within it, as one can see in acute osteomyelitis. The high pressures produced by small cages are presumably the reason for their clinical failure. Much research has been devoted to identify pain sources in the posterior annulus. However, if indeed the posterior annulus was a major player as a pain source, it is difficult to see why disc degeneration would not always be associated with pain, as the annulus is invariably deformed, and has various tears and fissures, despite the segment being painless.

Flexible stabilization

Flexible stabilization is a commonly used term to describe various systems that have been developed which allow spinal movement, but restrict its range. They were based on the concept that they permitted only restricted movement within the range of normal movement. We believe that they work either because they restrict movement to a zone or range where normal or near normal loading may occur, or they prevent the spine adopting a position where abnormal loading may occur.

Graf ligament

The Graf ligament system was one of the first relatively widely practiced methods of soft stabilization (Fig. 1). It consists of a non-elastic band as a ligament to connect the pedicle screws across the segment to be stabilized, to lock the segment in full lordosis. The concept was that, once the facet joints were locked, it would stop rotation. The inventor Henri Graf [10] was of the view that "instability" was related to the development of an abnormal rotatory movement, and if this were stopped, the system would still allow limited flexion, but within the range of normal flexion, which would therefore probably not be painful. There was no clinical or experimental basis for his views as to the cause of instability, but despite this, a clinical review and a biomechanical study carried out by our team at the Centre for Spinal Studies and Surgery in Nottingham

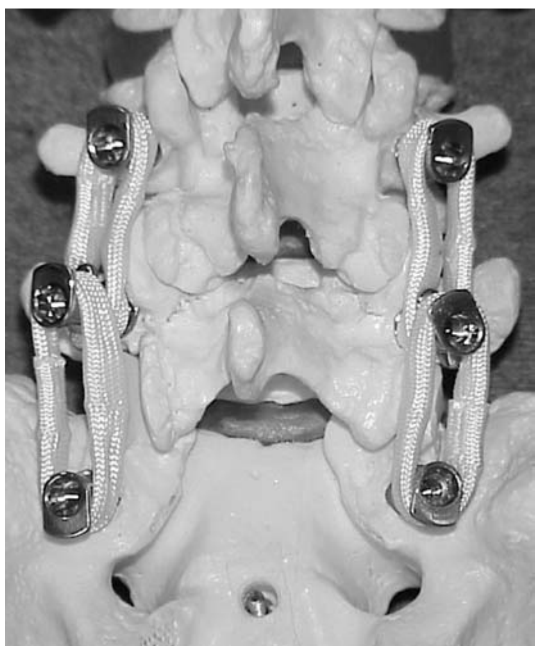

Fig. 1 Graf ligament system, applied to two adjacent motion segments in a spine model

showed that the Graf ligamentoplasty procedure had significant clinical success, with results similar to fusion [11]. It has the theoretical disadvantage that it overloads the posterior annulus, which, according to our earlier disc pressure profilometry study [18], was associated with a painful disc. It is somewhat uncertain as to whether success was related to the restriction of motion, or to the transfer of load to the posterior aspect removing loading from the anterior part of the disc. Our study [11] demonstrates that application of Graf ligament certainly transfers the load to the posterior annulus, and this may well be the explanation of its late failure! Graf ligamentoplasty procedure also produces a significant increase in lateral canal stenosis, especially if there is any preexisting degenerative change in the facet joints or in-folding of the ligamentum flavum, owing to the marked lordosis of the segment instrumented, and indeed early clinical failure was often associated with this surgical complication.

Dynesys

In the recently introduced Dynesyssystem (Sulzer Spine-Tech) (Fig. 2), the stabilization is achieved by connecting the pedicle screws with a non-elastic ligament, very similar to the Graf system, except that there is a plastic cylinder around the ligament. The plastic cylinder between the screw heads limits the degree of lordosis that can be created. The ligament is threaded through the cylinder and pulled tightly, with 300 N force, approximating the two screw heads to the extent that the interposed cylinder allows. As the posterior ligament is not elastic, flexion compresses the disc, and the axis of flexion is the posterior ligament, well posterior to the normal axis of flexion. Active extension will open up the anterior annulus without compression of the posterior annulus. Theoretically, lordosis can be achieved by the action of the spinal extensor muscles, and in extension the cylinder will take increasing load.

The early results of the Dynesys are promising. There are reports of some dramatic successes and some failures. The developers of the system claim it works by preventing so-called "parasitic" or "abnormal" movement. However, in addition to restricting the range of movement, it may also unload the disc if the patient achieves a position of lordosis, so that the plastic cylinder becomes weight bearing. However, lordosis and load sharing by the plastic cylinder depends very critically on the placement of the implant, and on the ability of the patient to achieve lordosis with his extensor muscles. Rajaratnam and co-workers recently reviewed [25] a group of 60 patients treated with Dynesys, with postoperative standing films with a plumb line. These patients did not achieve lordosis at the stabilized segments, although in some patients appropriate sagittal balance was achieved by extension above the instrumented segments. Of greater potential consequence, it was noted that, where the cylinder was placed with too much distraction, it leads to kyphosis of the segment. It is a common experience that kyphosis, if seen after disc excision, is associated with a higher incidence of back pain.

Fig. 2 Dynesis system, applied to two motion segments in a spine model

Leeds-Keio ligamentoplasty for spondylolisthesis

Mochida et al. [19, 20] reported an innovative method of posterior stabilization in which the Leeds-Keio artificial ligament was used as a nonrigid implant to stop movement in degenerative spondylolisthesis. They used fabric ligament, originally developed for reconstruction of anterior cruciate ligament, to tie it round drill holes through the pars of the adjacent vertebrae. In a biomechanical study on a porcine model [32], they found the system could effectively stop movement of the affected spinal segment even after cyclical loading of up to 1500 cycles. In a subsequent report [20], they compared the results of syndesmoplasty with ligament with that of instrumented fusion in a group of patients, and found no difference in outcome. They concluded that the non-rigid stabilization can produce an equally good result as compared to fusion, in patients with degenerative spondylolisthesis.

Fulcrum-assisted soft stabilization (FASS)

The fulcrum-assisted soft stabilization (FASS) system [28] (Fig. 3) was developed to address what was perceived as disadvantages of the Graf system. In this system, a fulcrum is placed between the pedicle screws, in front of the

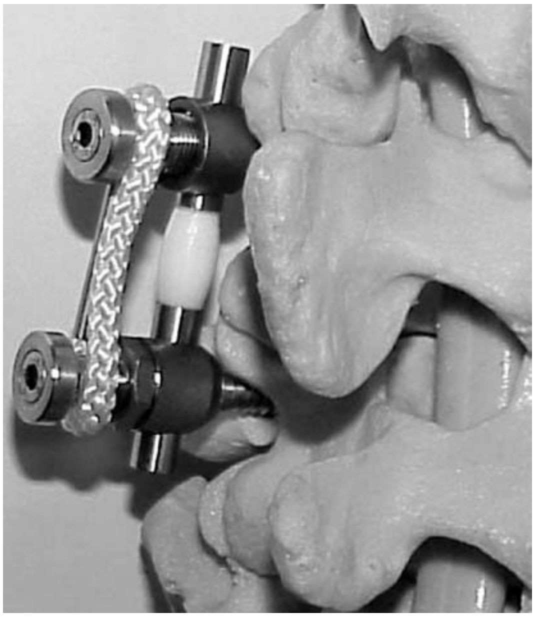

Fig. 3 Fulcrum-assisted soft stabilization system (FASS), applied here to the left side of one motion segment in a spine model. The ligament is elastic. The two fulcrums are fully flexible and each is placed anterior to the ligament and between the pedicle screws on either side, to permit flexion-extension, lateral bending and rotation of the motion segment, but resist axial compression. The compression force applied by the elastic ligament is converted by the fulcrum into a distraction force in front, thereby unloading the disc. The fulcrum shares the load with the disc. The system is still under development

ligament. The fulcrum distracts the posterior annulus. When the elastic ligament is placed posterior to the fulcrum, to compress the pedicle screw heads, the fulcrum transforms this posterior compression force to an anterior distraction force, which distracts the anterior annulus. The ligament creates the force that produces a lordosis, and it is not dependent on active muscle action, unlike in the Dynesys system. It is imperative that the FASS device should be inserted with sufficient tension in the ligament to create the required lordosis.

There are two problems commonly experienced with the Graf system:

1. The lordosis that the Graf ligament system invariably produces results in narrowing of the lateral recess, leading to root entrapment, especially if there was any preexisting facet arthropathy.
2. The Graf system increases the loading of the posterior annulus, which is a feature of the painful degenerate disc.

The presence of the fulcrum prevents both these problems.

FASS system can unload the disc, unaided by the posture or muscle action. It addresses a major defect of the Dynesys system, insofar as it does not allow the segment to be put into kyphosis. The lordosis is created by the implant, and is not dependent on the patient's ability to achieve lordosis with his or her own muscles.

The implant experimentally does unload the disc. It was found in the cadaver experiment that the degree of unloading is directly related to the stiffness produced by the system [29]. In other words, more flexibility is lost as greater unloading of the disc is achieved by adjustment of the tension in the ligament and the fulcrum. Clearly, if a very stiff system is implanted, then screw loosening and implant failure is more likely to occur in the long term. To maintain the normal physiological environment in the disc, it may desirable to unload the disc partially, and allow the segment a mobility as close to normal as possible. The fulcrum is thus only a load-sharing device. The system is still under development and a clinically applicable prototype is yet to be available.

Summary

In summary, there is enough evidence in the literature and support in common clinical experience to justify the hypothesis that chronic low-back pain is load related and not movement related, as the term "instability" would suggest. The concept of spinal ligamentoplasty or flexible stabilization is that it allows movement of the segment, and unloads the disc to a degree. The partial clinical success of the Graf and the Dynesys systems clearly show that back pain can be alleviated despite allowing movement. These systems may succeed in those patients where pain is related to abnormal loading in flexion. It is hypothesized that a desirable flexible stabilization system should combine overall disc unloading with restricting movement to a range where abnormal loading does not occur. The advantage of preserving movement is not related to the clinical need to bend one's back, but the need of the spine to be able to achieve sagittal balance in the varying postures required for daily living.

Philosophically, the true cure of a degenerative disc disease is a reversal of the degenerative process. This requires that the disc is rehydrated, and regains its height, mobility and load-bearing function. The only therapeutic approach towards this goal at present is gene therapy [9, 23], which aims at rejuvenating the chondrocytes in the nucleus of the disc. Unfortunately, the hostile and somewhat anoxic environment in a degenerate and fully loaded disc may not allow the rejuvenated cells inserted to survive and function. Soft stabilization may provide a sufficiently favourable environment in the disc for a gene therapy to achieve its goal.

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