Abstract

Purpose: To determine why A.D.R.’s fail by examining results of 91 patients in F.D.A. studies performed at a single I.D.E. site with minimum two-year follow-up.

Methods: To minimize variables, every patient undergoing A.D.R. at one I.D.E. site by two surgeons were evaluated for clinical success. Failure was defined as less than 50% improvement in O.D.I. and V.A.S. or any additional surgery at index or adjacent spine motion segment. This criterion for success was more stringent than F.D.A. guidelines, which require only a 25% improvement in O.D.I. and V.A.S. for clinical success.

Three A.D.R.’s were evaluated: Maverick™ (M) 25 patients, Charité™ (C) 31 patients, Kineflex ™(K) 35 patients. All procedures were one level performed at L4-5 or L5-S1. Demographics and inclusion/exclusion criteria were similar and will be discussed. Facet pain was diagnosed by facet block and significant clinical improvement after facet rhizotomy.

Results: Overall clinical failure occurred in 26%, (24 of 91 patients) at two-year follow up. Clinical failure occurred in: (M) 28%, (7 of 25 patients); (C) 39%, (12 of 31 patients); (K) 14%, (5 of 35 patients). The type of A.D.R. makes a difference. Causes of failure included: facet pathology 50% of failure patients,(12 of 24). Implant complications occurred in 5% of the total patients and 21% of the failure patients, (5 of 24). Patients with additional orthopedic or medical pathology or disability/narcotic issues making them unable or unwilling to fill out follow-up forms specific to their A.D.R. occurred in 29% (7 of 24), of the failure group. Despite the fact these patients were considered failures based on O.D.I. and V.A.S., they reported a 92% satisfaction with the A.D.R. and would repeat the surgery for the same result. Interestingly, A.D.R. patients are often either a clinical success at three-month follow-up (home run) or a possible failure (strike out). Only five patients went from a success to failure after three months. One was an infection one year after A.D.R. and four patients developed additional pathology unrelated to their A.D.R. Only one patient went from a failure to success after a facet rhizotomy one year after A.D.R.

Conclusions: Seventy-four percent of patients after A.D.R. met strict clinical success after two-year follow-up. The clinical success verses failure rate did not change from their three-month follow-up in 85 of the 91 patients (93%). Home run verse strike out can be determined early. Failures occurred due to: facet pain, 50% of the time; implant complications in 21%; and additional unrelated pathology or disability/narcotic issues resulting in form filling not specific to their ADR in 29% of patients. Implant type appears to impact clinical success. These results indicate overall clinical success can be improved most by patient selection and implant type.
Introduction
The purpose of this study is an attempt to ascertain the reason patients undergoing lumbar artificial disc replacement (LADR) do not meet FDA definitions of clinical success or do not meet a more stringent definition of success.

The lumbar spine motion segment is a three-joint complex. The two vertebrae of a motion segment are connected via a disc anteriorly and two facet joints posteriorly. Any of these structures can cause chronic low back pain. The FDA indication for LADR is discogenic low back pain. Biomechanical studies have shown an annular tear can result in a decrease in rotational constraints resulting in increased stress on the facet joints. In addition, as a disc space collapses secondary to dehydration, more compressive forces occur across the facet joints.

The exact etiology of a patient’s low back pain remains difficult to specifically identify. MRI scanning, discography and facet blocks can be used in an attempt to identify a specific pain generator. Patients undergoing LADR are generally diagnosed via history and physical examination indicating severe midline pain aggravated with activities and relieved typically in a supine position. Symptoms may be aggravated by sitting, lifting, twisting, bending and stooping.

Review of the IDE clinical data reveals overall clinical success of 63.5% in the ProDisc-L IDE study and 63.6% in the Charité IDE study. Reoperations occurred in six patients in the ProDisc-L IDE study. Four patients had reoperation secondary to migration of either the ultra-high molecular weight polyethylene (UHMWPE) inlay or entire implant migration. Two additional patients required reoperation secondary to a technical error of inserting the UHMWPE inlay in one patient and a second patient was converted to a fusion due to unresolved pain after the ADR. Eleven patients (5.4%) in the Charité group required reoperation. The authors did not detail the reasons. In neither study is there any discussion or explanation for the patients who did not meet FDA clinical success. This would amount to 36.5% of the patients in the ProDisc IDE and 36.4% of patients in the Charité IDE.

Several studies have concluded the interesting observation that patients following LADR generally achieve their 24-month follow-up results at three months post operative. In general, a patient’s improvement in Oswestry disability index (ODI) and visual analogue scale (VAS) are present by their three-month follow-up. The vast majority of patients do not significantly change from what their clinical result is at this early follow-up. Patients generally are either a “home run” or “strike out” by their three-month follow-up.

Material and Methods
This study involves an analysis of every patient in an FDA IDE study undergoing a LADR by the senior author at a single FDA IDE site. Every patient was part of two different FDA IDE studies. The first study involved a prospective randomized study comparing the results of the Maverick LADR versus LT cage with BMP. FDA clinical success was defined as a 20% improvement in Oswestry disability index (ODI) from pre-op to two-year follow-up with no reoperations and no neurologic deterioration. There were 25 patients in this study.

The second FDA study involved a prospective randomized comparison of the Charité versus Kineflex LADR. Clinical success in this study required a 15-point improvement in ODI from
pre-op to two-year follow-up with no deterioration of neurologic status or reoperation. This study consisted of 35 patients with a Kineflex artificial disc and 31 patients with a Charité artificial disc.

These 91 FDA IDE patients from two studies provide the basis for this paper. The cases were consecutively performed. The follow up at 2 years is 100%.

Chart 1

<table>
<thead>
<tr>
<th>Methods</th>
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<tbody>
<tr>
<td>91 Patients in F.D.A. I.D.E Lumbar A.D.R. Studies</td>
</tr>
<tr>
<td>Three A.D.R.'s</td>
</tr>
<tr>
<td>Maverick: 25 patients</td>
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<tr>
<td>Charite: 31 patients</td>
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<tr>
<td>Kinflex: 35 patients</td>
</tr>
<tr>
<td>Single site with the same two surgeons, surgical staff and clinical staff</td>
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<td>Minimum 2 year follow-up</td>
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Kineflex versus Charité versus Maverick

<table>
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<tr>
<th></th>
<th>Kineflex Disc</th>
<th>Charité</th>
<th>Maverick Disc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Subjects</td>
<td>35</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>Male</td>
<td>15</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Female</td>
<td>18</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>Age, mean (SD), years</td>
<td>40.1 (10.01)</td>
<td>40.8 (7.68)</td>
<td>37</td>
</tr>
<tr>
<td>Body Mass Index, mean</td>
<td>26.6 (3.39)</td>
<td>26.0 (3.40)</td>
<td>27</td>
</tr>
<tr>
<td>Surgery Level: L4-5</td>
<td>6 (18%)</td>
<td>4 (12.9%)</td>
<td>6 (24%)</td>
</tr>
<tr>
<td>Surgery Level: L5-S1</td>
<td>27 (81.8%)</td>
<td>27 (87.1%)</td>
<td>19 (76%)</td>
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</table>

Definition of Clinical Success
The definition of clinical success for the basis of this paper required a 50% improvement in ODI from pre-operative through two-year follow-up. This is more stringent than the 15-point improvement required for the FDA IDE trials. In addition, any patient undergoing a reoperation or showing signs of neurologic deterioration were considered a failure. This more stringent definition of clinical success was utilized to provide more patients for critical evaluation and a 50% improvement in ODI was felt to be a reasonable stringent definition of success. Glassman, et al. published a study determining the level where patients perceive clinical success. They determined a patient required a 20% improvement in SF36 and an approximate 40% decrease in
ODI and VAS before the patient perceived lumbar fusion as a success. This more stringent definition of success was thus felt reasonable.

**Facet Pain**
Facet pain was diagnosed in patients who complained of continued pain after LADR. These patients typically had pain worse with extension and often unilateral off midline. These patients underwent intra-articular injection of the facet joint under fluoroscopic control. Each facet joint was anesthetized with 0.25ml of 0.25% Marcaine and 0.25ml of Depo-Medrol. These patients required at least an 80% improvement in their symptoms following this injection. In those patients achieving at least an 80% improvement in their symptoms after the first facet injection, if their pain returned, a second injection was performed. Again, if they achieved an 80% reduction in their pain, they were considered to have continued pain secondary to facet pathology.

**Results**
Based on a strict definition requiring at least a 50% improvement in ODI at two-year follow-up with no reoperations or deterioration in neurologic status, overall clinical failure occurred in 27% (24 of 89 patients) at two-year follow-up. Clinical failure occurred in 28% (7 of 25) of the Maverick patients, 39% (12 of 31) of the Charité patients and 15% (5 of 35) of the Kineflex patients.

<table>
<thead>
<tr>
<th>Chart 2</th>
<th>Utilizing A Strict Definition of Failure 26% (24 of 91 patients)</th>
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</thead>
<tbody>
<tr>
<td>▪ Maverick: 28% (7 of 25 patients)</td>
<td></td>
</tr>
<tr>
<td>▪ Charite: 39% (12 of 31 patients)</td>
<td></td>
</tr>
<tr>
<td>▪ Kinelflex: 15% (5 of 35 patients)</td>
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</table>

**Cause of Failure**
Facet pathology was the etiology of failure in 50% (12 of 24) of the failure patients. All of these patients were diagnosed as having facet pain based on two separate injections as defined in the methods section. Nine of these patients went on to have percutaneous facet rhizotomy performed. None of these 12 patients have gone on to any additional surgery. Presently, they are living with their symptoms.

| Chart 3 |
Reasons for Failure

- **Failure Due to Facet Pain:**
  - 50% (12 out of 24 patients)
  - Facet pain diagnosed by >80% relief from 2 facet blocks and relief with rhizotomy

- **Charité:** 7
- **Kineflex:** 3
- **Maverick:** 2

Implant complications occurred in five of the total 91 patients and 21% (5 of 24) of the failure patients. These five patients had the following complications. One Maverick patient became infected 18 months after the initial surgery requiring surgical debridement and fusion. One Charité patient underwent revision of the implant within 24 hours post initial operation to a more midline position. One Charité patient underwent a posterior fusion secondary to bilateral pedicle fractures occurring six weeks post operatively. One Charité patient underwent a posterior fusion secondary to an implant invaginating into the L4 vertebral body at six weeks post op. One Kineflex patient subluxed the sacral endplate anteriorly approximately 4mm and underwent conversion to an anterior lumbar interbody fusion within 24 hours of the index operation.

**Chart 4**

- **Failure Due To Implant Complications**
  - 21% of overall failures (5 out of 24 patients)
  - 1 Infection: 18 months post-op
  - 4 Re-operations: 2 within 24 hours
    - All Charité/Kineflex: 2 within 6 weeks

Patients with additional orthopedic or medical pathology or disability/narcotic issues making them unable or unwilling to fill out follow-up forms specific to their artificial disc replacement occurred in 29% (7 of 24) of the failure group. Despite the fact these patients were considered failures based on ODI and visual analog scale (VAS), they reported a 92% satisfaction rate with the artificial disc and would repeat the surgery for the same result.
Reasons for Failure

**Failure Due to Additional Orthopedic Pathology:**
- 29% (7 out of 24 patients)
- These 7 patients were failures due to <50% improvement in O.D.I. yet 92% reported satisfaction with A.D.R. and would repeat surgery for same result.

Overall Cause of Clinical Failure

- Facet Pain = 50%
- Implant Complications = 21%
- Complex Patients = 29%

Chart 7

**Implant Comparison**

- **Facet Pain:**
  - Charite: 7
  - Kineflex: 3
  - Maverick: 2
- **Re-operations:**
  - Maverick: 1 (Infection)
  - Charite: 3 (Pedicle fracture, collapse, mal-position)
  - Kineflex: 1 (Subluxation)
- **Failure Rate:**
  - Maverick: 28%
  - Charite: 39%
  - Kineflex: 14%

Interestingly, ADR patients are either a clinical success at three-month follow-up (home run) or possible failure (strike out). Only five patients in the entire group of 91 patients went from a success to failure after three months. One patient had an infection 18 months after the initial artificial disc replacement, and four patients developed additional pathology unrelated to their artificial disc replacement. These patients did not have additional surgery but were considered failures due to the ODI scores. Only one patient went from failure to success after facet rhizotomy one year after artificial disc replacement.

**Discussion**

The lumbar spine motion segment is a three-joint complex. The two vertebrae of a motion segment are connected via a disc anteriorly and two facet joints posteriorly. Any of these structures can cause chronic low back pain. The FDA indication for LADR is discogenic low back pain.\(^{10,11}\) Biomechanical studies have shown an annular tear can result in a decrease in rotational constraints resulting in increased stress on the facet joints.\(^{5-8}\) In addition, as a disc space collapses secondary to dehydration, more compressive forces occur across the facet joints.
The exact etiology of a patient’s low back pain remains difficult to specifically identify. MRI scanning, discography and facet blocks can be used in an attempt to identify a specific pain generator. Patients undergoing LADR are generally diagnosed via history and physical examination indicating severe midline pain aggravated with activities and relieved typically in a supine position. Symptoms may be exaggerated by sitting, lifting, twisting, bending and stooping. Generally, patients have desiccation on a sagittal T2 weighted MRI scan. Discography has been shown to be helpful in diagnosing patients with discogenic back pain. Nevertheless, most authors would agree today that the discogram presents inconsistent results in most studies and cannot solely and reliably indicate the pain generator in back pain syndrome. General contraindications to LADR are severe disc space collapse, moderate to severe facet degeneration or severe symptomatic facet pain.

Review of the IDE clinical data reveals overall clinical success of 63.5% in the ProDisc-L IDE study and 63.6% in the Charité IDE study. Reoperations occurred in six patients in the ProDisc-L IDE study. Four patients had reoperation secondary to migration of either the ultra-high molecular weight polyethylene (UHMWPE) inlay or entire implant migration. Two additional patients required reoperation secondary to a technical error of inserting the UHMWPE inlay in one patient and a second patient was converted to a fusion due to unresolved pain after the ADR. Eleven patients (5.4%) in the Charité group required reoperation. The authors did not detail the reasons. In neither study is there any discussion or explanation for the patients who did not meet FDA clinical success. This would amount to 36.5% of the patients in the ProDisc IDE and 36.4% of patients in the Charité IDE.

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Siepe reported on 99 patients who underwent either non-segmental TDR at L4-5 (group A = 22 patients), mono-segmental TDR at L5-S1 (group B = 57 patients) or bi-segmental TDR at L4-5 and L5-S1 (group C = 20 patients). The follow-up was 12 months. All patients underwent pre-operative facet joint injections to rule out facet pain prior to TDR. They reported an overall revision rate of 8.1%. Sixteen patients (16.2%) underwent fluoroscopically guided facet injections post operatively with significant relief. Most of the patients with post operative ongoing facet pain had a TDR at L5-S1.

A wide range of complication rates from 1-40% has been reported in the literature following LADR with most reports ranging between 10-20%. McAfee, et al. reported a reoperation rate of 8.8% (52 of 589 patients) with the Charité. Complications reported include access related complications with sympathectomies, retrograde ejaculation, hematomas or seromas. Post operative complications reported include heterotopic ossification, persisting facet joint problems, sub-optimal placement of the implant, adjacent segment disc herniation, superficial wound infection.
An increasing number of clinical, radiographic and biomechanical studies suggest posterior motion segment structures, primarily facet joints, are a major etiology of continuing pain or development of pain following LADR. Sagittal imbalance following LADR is an important factor to developing facet pain. Implant position within the motion segment has been reported to have profound effects on posterior joint pain. A posterior center of rotation of the LADR emulates normal spinal motion kinematics. An anterior center of rotation of the LADR increases facet forces.

Removing the anterior longitudinal ligament in the process of insertion of LADR has been shown in numerous studies to increase stresses on the facet joints. This study indicates the type of artificial disc replacement in terms of its kinematics appears to influence the incidence of post operative facet pain. Three artificial discs are reported in this study. Biomechanically, the Kineflex and Maverick discs both have a posterior center of rotation and would be considered more constrained than the Charité. The Charité has a central center of rotation with a center core which allows 2mm of translation. Thus, flexion, extension and side bending are all associated with a coupled motion. This unconstrained design may result in increased strain on the facet joints resulting in the higher incidence of facet pain reported in the study with the Charité.

Five of the 91 patients in this study had additional surgery at the index level. Four of these occurred within eight weeks of the index surgery and one patient had a late (18 months) infection. This is consistent with previously reported revision rates.

Clinical result issues specific to patients in an FDA IDE study are the seven of 24 patients (29%) in the failure group who did not have facet pain or device problems. These seven patients were considered failures because they reported on their FDA IDE follow-up forms additional orthopedic, medical pathology or disability/narcotic issues resulting in a lack of adequate improvement in ODI or VAS. These patients were clinical failures only because of their failure to report at least 50% improvement in ODI and VAS at two-year follow-up. When specifically asked about their LADR, 92% of these patients were highly satisfied with the disc replacement and would do the surgery again for the same result. When specifically questioned as to why they did not report significant improvement in ODI or VAS, their explanations related to their additional orthopedic, medical pathology or psychosocial issues. These results should caution FDA IDE investigators to possibly exclude complex orthopedic patients or any patient with disability/narcotic issues who may not be able to accurately fill out forms specific to the results of their LADR.

Conclusions:

Seventy-four percent of patients after A.D.R. met strict clinical success after two-year follow-up. The clinical success verses failure rate did not change from their three-month follow-up in 85 of the 91 patients (93%). Home run verse strike out can be determined early. Failures occurred due to: facet pain, 50% of the time; implant complications in 21%; and additional unrelated pathology or disability/narcotic issues resulting in form filling not specific to their ADR in 29% of patients. Implant type appears to
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