**Supplemental Digital Content**

**Table 1: Details of Studies**

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| **Author****(Year)** | **Study Design** | **Population** | **Purpose** | **Inclusion/Exclusion** | **Treatment** | **How ASP Defined****and Classified** |
| **TDR versus Fusion** |
| Berg(2009) | Randomized controlled trialF/U time: 48 months | N = 152Age: 39.4 ± 8.0Mean age: 40 years (range, 21–55 years)Sex: 41% maleF/U rate:Total 152/152 (100%)TDR 80/80 (100%)Fusion 72/72 (100%) | Compare TDR with posterior fusion, in terms of clinical outcome, in patients referred to spine clinic for surgical evaluation | Inclusion:* Age 20 to 55 years
* LBP with or without leg pain for > one year
* Failed three months of conservative treatment
* Confirmation of disc degeneration on MRI
* Oswestry > 30 or VAS 50/100 week before inclusion

Exclusion:* Spinal stenosis requiring decompression
* Moderate or worse facet joint arthritis
* Three or more painful levels at examination
* No obvious painful level with diagnostic injection
* Isthmic spondylolysis or olisthesis
* Degenerative spondylolisthesis > 3 mm
* Major deformity
* Manifest osteoporosis
* Previous lumbar fusion or decompression with postoperative instability
* Compromised vertebral body
* Previous spinal infection or tumor
 | TDR (N = 80)* Charité
* Prodisc
* Maverick

Age: 40.2 ± 8.1Sex: 40% maleFusion (N = 72)* Posterior lateral fusion (n = 44)
* Posterior lumbar interbody fusion (n = 28)

Age: 38.5 ± 7.8Sex: 42% male | Operation at an adjacent level. No description of ASP conditions. |
| Guyer\*(2009) | Randomized controlled trialF/U time: 60 months | N = 233Mean age: 40 years (range, 19–60 years)Sex: 53% maleF/U rate:Total 133/233 (57%)Charité NRALIF NR | Compare the safety and effectiveness at the five-year follow-up time point of lumbar TDR using the Charité artificial disc with that of anterior interbody fusion with BAK cages for the treatment of single-level degenerative disc disease from L4 to S1 | Inclusion:* Age 18 to 60 years
* Symptomatic DDD confirmed by discography
* Single level DDD at L4-L5 or L5-S1
* Oswestry > 30 or VAS > 40/100
* Failed 6 months of nonoperative care
* Back and/or leg pain with no nerve root compression

Exclusion:* Previous thoracic or lumbar fusion
* Current or prior fracture at L4, L5, or S1
* Symptomatic multilevel degeneration
* Non-contained herniated nucleus pulposus
* Spondylosis
* Spondylolisthesis > 3 mm
* Scoliosis > 11°
* Mid-sagittal stenosis < 8 mm
* Spinal tumor or infection
* Osteoporosis, osteopenia, or metabolic bone disease
* Facet joint arthrosis
* Psychosocial disorder
* Morbid obesity
* Metal allergy
* Use of bone growth stimulator
* Participation in another study
* Arachnoiditis
* Chronic steroid use
* Autoimmune disorder
* Pregnancy
* Other spinal surgery at affected level (excluding discectomy, laminotomy, laminectomy, without accompanying facetotomy or nucleolysis at the same level to be treated)
 | Charité artificial disc (N = 90)Age: 40.0 ± 8.6Sex: 52% maleAnterior lumbar interbody fusion with BAK cages (n = 43)Age: 38.8 ± 8.7Sex: 56% male | Operation at an adjacent level. No description of ASP conditions. |
| **Motion Preservation Devices versus Fusion** |
| Kanayama(2009) | Retrospective cohortF/U time: 48 months | N = 224Mean age: 63 years Sex: 42% maleF/U rate:Total 218/224 (97.3%)Graf 65/67 (97.0%)PLF 75/77 (97.4%)PLIF 78/80 (97.5%) | Determine the prevalence and nature of adjacent segment deterioration after posterior ligamentoplasty, posterolateral lumbar fusion or posterior lumbar interbody fusion | Inclusion:* Degenerative olisthesis
* Isthmic olisthesis
* Herniated disc
* Spinal stenosis
* Foraminal stenosis

Exclusion:* Degenerative scoliosis
 | Graf ligamentoplasty (n = 65)Mean age: 63 years Sex: 34% malePosterior lateral fusion (n = 75)Mean age: 64 years Sex: 41% malePosterior lumbar interbody fusion (n = 78)Mean age: 60 years Sex: 49% male | Adjacent segment disease defined as radiculopathy associated with newly developed pathologies at L1-L2, L2-L3, L3-L4, and L5-S1. ASD diagnosed on the basis of clinical presentation, not only radiographic findings.Asymptomatic adjacent segment pathologies were not included. |
| Kanayama(2001) | Retrospective cohortF/U time: 60 months | N = 70Mean age: 57 years Sex: 49% maleF/U rate:Total 45/70 (64.3%)Graf 18/28 (64.3%)PLF 27/42 (64.3%) | Assess the adjacent segment morbidity of Graf ligamentoplasty compared with posterolateral fusion in which instrumentation was used | Inclusion:* Flexion instability
* No or minimal disc space narrowing
* Degenerative spondylolisthesis
* Massive disc herniation
* Spinal stenosis
* Isthmic olisthesis
* Recurrent disc herniation

Exclusion:* NR
 | Graf ligamentoplasty (n = 18)Mean age: 55 ± 15 years Sex: 44% malePosterior lateral fusion (n = 27)Mean age: 58 ± 11 years Sex: 52% male | Radiographic evidence of adjacent segment morbidity includes disc space narrowing, spur formation, spondylolisthesis, and vacuum phenomenon.Clinical evidence of adjacent segment morbidity was determined by the rate of salvage operation for adjacent segment lesions. |
| Kaner (2010) | Prospective cohortF/U time: Dynamic: 38 monthsRigid: 44 months | N = 46Mean age: 62 years (range, 45-89 years)Sex: 28% maleF/U rate:Total 46/46 (100%)Dynamic 26/26 (100%)Rigid 20/20 (100%) | To compare posterior dynamic transpedicular stabilization and posterior rigid transpedicular stabilization with fusion after decompression in the treatment of degenerative spondylolisthesis | Inclusion:* Single level grade I or II degenerative spondylolisthesis causing central and/or lateral recess syndrome
* Failed previous medical treatment

Exclusion:* Isthmic spondylolisthesis
* Degenerative spondylolisthesis at more than one level
* History of previous lumbar fusions
* Infections of the spine
* Systemic diseases
 | Lumbar decompression and posterior dynamic transpedicular stabilization (n = 26)Mean age: 64 years Sex: 23% maleLumbar decompression and rigid transpedicular stabilization with fusion (n = 20)Mean age: 62 years Sex: 35% male | Operation at an adjacent level. No description of ASP conditions. |
| Korovessis (2004) | Randomized controlled trialF/U time: mean 47 ± 14 months | N = 45Mean age: 62 years Sex: 76% maleF/U rate:Total 45/45 (100%)Dynamic 15/15 (100%)Semi-rigid 15/15 (100%)Rigid 15/15 (100%) | To compare the short-term effects of rigid versus semi-rigid and dynamic stabilization on the global and segmental lumbar spine profile, subjective evaluation of the result, and the associated complications | Inclusion:* Symptomatic degenerative lumbar spinal stenosis for at least one year

Exclusion:* Prior spine surgery
* Active infection
* Congenital deformity
 | Twinflex Dynamic stabilization (n = 15)Mean age: 62 ± 10 years Sex: NRSemi-rigid Claris instrumentation (n = 15)Mean age: 59 ± 16 years Sex: NRRigid Segmental Contouring System (n = 15)Mean age: 65 ± 9 years Sex: NR | Adjacent segment degeneration is the presence of olisthesis, osteophytes, and disc degeneration above or below the instrumented spine. |
| Satoh(2006) | Retrospective cohortF/U time: 60 months  | N = 398Mean age: 40 years Sex: 72% maleF/U rate:Total 351/398 (88.2%)Discectomy NRPLIF NR | To examine whether lumbar disc herniation with massive extrusion and/or segmental instability can be an indicator for spinal fusion or not, by comparing the outcome of posterior lumbar interbody fusion and discectomy alone | Inclusion:* Massive herniation defined as a complete block on myelogram
* Segmental instability defined as anterior slip > 3 mm and/or local kyphosis of > 5° on lateral radiograph of maximal flexion

Exclusion:* NR
 | Discectomy (n = 177)Mean age: 39 years Sex: 67% malePosterior lumbar interbody fusion (n = 174)Mean age: 42 years Sex: 78% male | Adjacent level instability defined as anterior slip > 3 mm and/or local kyphosis > 5° at maximal flexion on lateral radiographs. |
| **Motion Preservation Devices versus Other Motion Preservation Devices** |
| Putzier (2005) | RetrospectivecohortF/U time: 34 months | N = 84Mean age: 37 years (range, 21–59 years)Sex: 61% male F/U rate:Total 82/84 (97.6%)Dynamic and nucleotomy 35/35 (100%)Nucleotomy alone 47/49 (95.9%) | To investigate the effect of dynamic stabilization compared with nucleotomy alone | Inclusion:* Therapy-resistant lumbar radicular complaints
* Disc prolapse shown on MRI
* Stage I disc degeneration according to Modic in a maximum of two segments
* Clinical symptoms equivalent to radicular syndrome

Exclusion:* Epidural adhesions and/or periradicular fibrosis after precedent nucleotomy depicted on MRI
* Significant changes in the posterior section of the motion segment like marked facet joint arthritis, absolute spinal stenosis
* Spondylolisthesis
* Lumbar scoliosis > 10°
* Stage II and III degenerative changes according to Modic
* Pain greater than stage II according to Gerbershagen
* Clinical, laboratory and/or radiologic signs of osteoporosis or other metabolic bone diseases
* Presence of malignant tumors
* BMI > 30 kg/m²
 | Dynamic stabilization and nucleotomy (n = 35)Mean age: 39 years (range, 23–58 years)Sex: 63% male Nucleotomy alone (n = 49)Mean age: 36 years (range, 21–59 years)Sex: 59% male  | Adjacent segment disease defined as presence of axis deviation or osseous remodeling processes, stenosis, or spondyloarthroses assessed by the degree of hydration of the intervertebral discs on T2 weighted sagittal MRIs. |

\*Longer-term outcome study of 60 months. Original study (Blumenthal & McAfee) done at 48 month F/U.

**Table 2: Level of Evidence of Included Studies**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Methodological Principle** | **Berg** | **Guyer** | **Kanayama** | **Kanayama** | **Kaner** | **Korovessis** | **Satoh** | **Putzier** |
| **(2009)** | **(2009)** | **(2009)** | **(2001)** | **(2010)** | **(2004)** | **(2006)** | **(2005)** |
| Study design |  |  |  |  |  |  |  |  |
| Randomized controlled trial | √ | √ |  |  |  | √ |  |  |
| Cohort Study |  |  | √ | √ | √ |  | √ | √ |
| Case Series |  |  |  |  |  |  |  |  |
| Statement of concealed allocation† | √ |  |  |  |  |  |  |  |
| Intention to treat† | √ | √ |  |  |  | √ |  |  |
| Independent or blind assessment |  |  |  | √ |  | √ | √ |  |
| Co-interventions applied equally | √ | √ | √ | √ | √ | √ | √ | √ |
| Complete follow-up of ≥ 80% | √ | \* | √ |  | √ | √ | √ | √ |
| Adequate sample size | √ | √ |  |  |  |  | √ |  |
| Controlling for possible confounding | √ | √ |  |  |  |  |  |  |
| Prospective study | √ | √ |  |  | √ | √ |  |  |
| **Evidence Level** | **II** | **II** | **III** | **III** | **III** | **II** | **III** | **III** |
| †applies to randomized controlled trials only\*The follow-up rate for both arms of this trial was very low; therefore, results should be interpreted with caution. |

**Table 3: Strength of Evidence**

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| Baseline Quality: HIGH = majority of article Level I/II; LOW = majority of article Level III/IVUPGRADE: Large magnitude of effect (1 or 2 levels); dose response gradient (1 level)DOWNGRADE: Inconsistency of results (1 or 2 levels); indirectness of evidence (1 or 2 levels); imprecision of effect estimates (1 or 2 levels) |
|  | **Strength of Evidence** | **Conclusions/Comments** | **Baseline** | **UPGRADE (levels)** | **DOWNGRADE****(levels)** |
| Question 1: Is there evidence that TDR is associated with a lower risk of radiographic or clinical ASP compared to fusion? |  |  |  |
| * TDR versus fusion
 |  **MODERATE** | The pooled risk of clinical ASP (treated surgically) was 1.2% and 7.0% in the TDR and fusion groups, respectively. The pooled relative risk of clinical ASP (treated surgically) comparing the fusion to the TDR group was 5.9, the pooled attributable risk was 5.8%, and the number needed to harm was 17.3. | * HIGH
 | * NO
 | * Imprecision (1)
 |
| Question 2: Is there evidence that other motion preservation devices are associated with a lower risk of radiographic or clinical ASP compared to fusion? |  |  |  |
| * Graf ligamentoplasty versus fusion
 | **LOW** | The pooled risk of clinical ASP was 2.4% and 8.9% in the ligamentoplasty and fusion groups, respectively. The pooled relative risk of clinical ASP comparing the fusion group to the Graf ligamentoplasty group was 3.7, the pooled attributable risk was 6.4%, and the number needed to harm was 15.4. | * LOW
 | * Large effect (1)
 | * Imprecision (1)
 |
| * Dynamic stabilization versus semi-rigid
 | **INSUFFICIENT** | There was only one reported observations of ASP in a fusion arm in two studies making this comparison. | * LOW
 | * NO
 | * Imprecision (1)
 |
| * Discectomy versus fusion
 | **INSUFFICIENT** | In a single study, the risk of radiographic ASP was 8.6% and 1.7% in the PLIF and discectomy groups, respectively. The risk of clinical ASP was 6.9% and 3.4% in the PLIF and discectomy groups, respectively. This difference was not statistically significant.  | * LOW
 | * NO
 | * Imprecision and single study (1)
 |
| Question 3: Is one type of motion preservation device associated with a lower risk of ASP compared with other types?  |  |  |  |
| * Dynamic stabilization with nucleotomy versus nucleotomy
 | **INSUFFICIENT** | There were no reported observations of ASP in either treatment arm in a single study. | * LOW
 | * NO
 | * Single study (1)
 |