Lumbar Arthroplasty (TECHNIQUES)

Last updated: September 2, 2023

Table of Contents

Detailed Table of Contents

PRINCIPLES

- introduced in the 1980s in Germany

- motion preservation - keeps adjacent segments from significantly progressive degeneration.
- in 2019, 65% of insurance providers cover single-level lumbar arthroplasty.

DESIGNS

<u>Core material:</u>

A) metal-on-metal – may cause gross metalosis around device
B) polyethylene core – may cause osteolysis!

<u>Core can be:</u>

A) mobile (**unconstrained**)
B) fixed to one of the end plates (**constrained**)

- biomechanical studies show no significant advantage of constrained (ProDisc-L) over an unconstrained device (Charité).
- unconstrained devices had higher ROM for axial rotation and lateral bending and lower ROM for flexion and extension.
- constrained prostheses with a small radius of curvature cause *increased facet joint loads* in extension while unconstrained prostheses that are free to translate during extension might find an equilibrium point between facet joint compression and capsulo-ligamentous tension.
- constrained device would cause increased facet loads caused by impingement during flexion and extension of the motion segment, whereas an unconstrained device would unload the facet joint.
- loading forces are absorbed in a constrained prosthesis, resulting in long-term facet preservation, whereas an unconstrained LDR, lacking inherent shear stability, would make the facets and posterior ligaments subject to increased forces resulting in an increased incidence of degenerative facet changes.

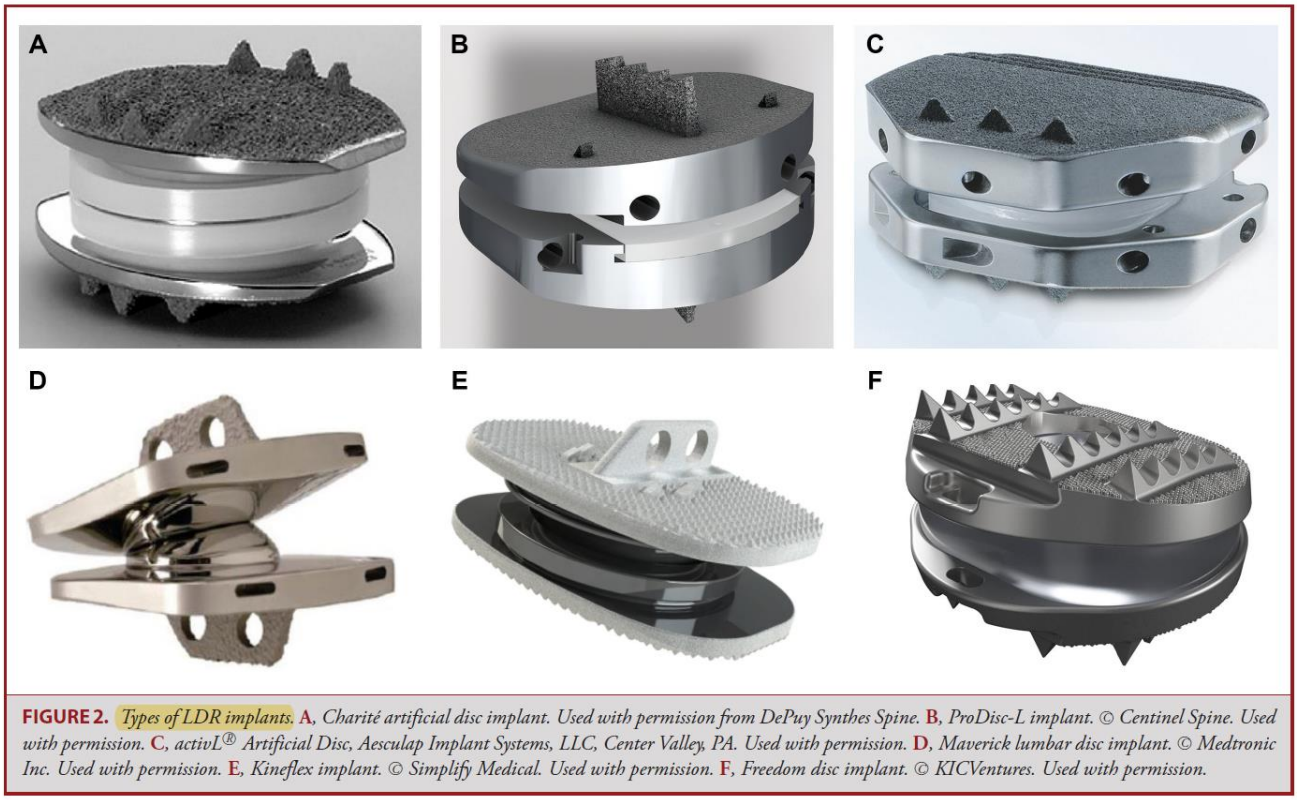


FIGURE 2. *Types of LDR implants.* A, *Charité artificial disc implant. Used with permission from DePuy Synthes Spine.* B, *ProDisc-L implant. © Centinel Spine. Used with permission.* C, *activL® Artificial Disc, Aesculap Implant Systems, LLC, Center Valley, PA. Used with permission.* D, *Maverick lumbar disc implant. © Medtronic Inc. Used with permission.* E, *Kineflex implant. © Simplify Medical. Used with permission.* F, *Freedom disc implant. © KICVentures. Used with permission.*

1. CHARITÉ (DePuy Spine) - made up of *plastic core* sandwiched between two *metal endplates*.
- early problems with implantation of the Charité artificial discs by the general spine surgeon community resulted in a number of reported serious adverse events to FDA and numerous litigation cases.
- no stop in translation - facets take beating!

2. Kineflex-L

3. activL - third-generation device (FDA approved in 2015)

INDICATIONS & REQUIREMENTS

Even precise placement of the implant and excellent surgical technique will not overcome poor patient selection for the procedure!

- **discogenic pain** associated with degenerative disc disease (DDD) at L3-S1 - diagnosis is difficult: back pain with mechanical loading (e.g. siting, leaning forward).
  - **discography** - only 20% pts need it but high false positive rate.
  - **MRI** is best study but it also is a grey zone.
  - **SPECT** may help (LA loves it).
  - **psychology clearance** is needed.
  - failed at least 6 months of conservative treatment.
  - skeletally mature patient
  - no more than grade I spondylolisthesis.
  - radiculopathy is not required
  - make sure facets are not generating pain! - try facet injections as rule out!
- ideal candidate is ***early on the Kirkaldy–Willis degenerative timeline*** than a typical patient for fusion.
- best results are obtained in patients:
  - younger than 40 yrs
  - single-level disc degeneration

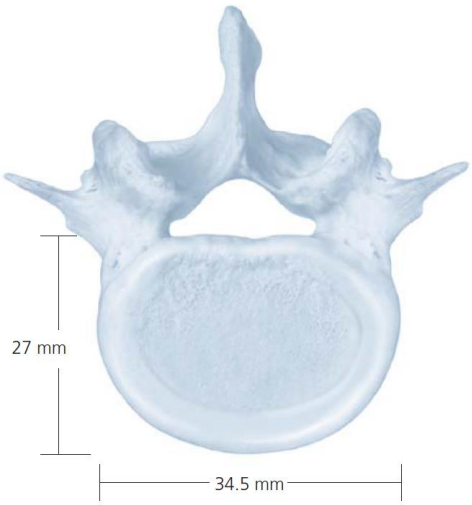
— > 50% remaining disc height (at least > 4 mm).

- not contraindications: microdiscectomy, prior fusion with adjacent segment disease, and disc replacement below a previous long-segment fusion for scoliosis
  N.B. 2-level replacements have higher revision rates!

Preop CT – to measure anatomy and select correct implant!

PRODISC L

- *one or two contiguous intervertebral levels* between L3 and S1.
  *FDA approved Prodisc L for 2 adjacent levels L3-S1 (BMI cut off for 2 levels is 35)
- vertebral end plates ≥ 34.5 x 27 mm



CONTRAINDICATIONS

1) active systemic infection / **infection** localized to the site of implantation
2) osteopenia with **DEXA** T-score < -1.0 (risk of atraumatic periprosthetic fractures); may use **SCORE questionnaire** to determine who needs DEXA. p. Op220 >>
   N.B. practically, use DEXA on everyone (DEXA of hip and spine - look for discrepancy as sclerotic vertebral endplates may elevate score falsely)
3) nonmobile segment
   N.B. Disc Replacement may maintain motion, but it cannot create motion!
4) > grade 1 spondylolisthesis
5) pars defect (spondylolysis).
6) bony lumbar stenosis (central or lateral recess).
7) isolated radicular compression syndromes, especially due to disc herniation
8) compromised vertebral bodies at affected level (due to current or past trauma).
9) posterior element disease such as a significant facet joint arthropathy or previous facet joint removal.
10) metal allergy (for metal-on metal implants).
11) Oswestry < 40

TECHNIQUE (PRINCIPLES)

APPROACH

- inserted via **anterior approach** (as for ALIF).
  Centinel Spine company claims can help to train access surgeons
- XL TDR (NuVasive) and Triumph (Globus Medical) - insertion techniques via **lateral** and **posterior** approaches, respectively – important for L2-4 levels!

SPACE PREPARATION

- box annulotomy slightly less wide than implant.
- complete and meticulous discectomy + end plate preparation + remobilization of the disc space
- endplates are prepared with a variety of curettes and Kerrison rongeurs.
  N.B. too extensive preparation and thinning of bony endplates can increase risk of implant subsidence and migration or cause heterotopic ossification
- flat-end plates (type I, by Yu-Bertagnoli classification) make implantation easier; vs. end plates that exhibit a type II or type III morphology require, respectively, either a keel or a spike mode of endplate stabilization.

IMPLANT POSITION

- anteriorly placed devices load facets 2.5 times more than the intact segment, and posteriorly situated devices correlated with smaller facet loads.
  Efforts should be made to have a centralized device! (ideally, an implant has maximum coverage over endplates)
- it is important to select the appropriate height to preserve mobility and prevent over distraction of the facet, which can irritate the facets and nerve roots (traction on the dorsal rami from over distraction are suspected sources of pain).

COMPLICATIONS

- excessive facet distraction → facet joint degeneration and acquired spondylolysis
- pedicle fracture
- device dislocations
- vertebral body split fractures (specifically with devices that have keels)
- development of scoliotic deformities and spontaneous fusion secondary to malpositioned implants.
- endplate violation → heterotrophic ossification (HO) – McAfee 5-point scale ranging from none to bridging bone across disc space.
  McAfee PC, Cunningham BW, Devine J, et al. Classification of heterotopic ossification (HO) in artificial disk replacement. J Spinal Disord Tech 2003;16:384–9.
- safety of metal-on-metal (MoM) implants:
  - metallic wear debris is less than in total hip replacements
  - serum ion level analysis (cobalt, chromium) found the greatest mean value at any follow-up point was less than 20% of Medicines and Healthcare Products Regulatory Agency recommended minimum value to merit monitoring hip replacement patients
- approach related; retrograde ejaculation (0.42-6% from injury to the superior hypogastric plexus), ureteral injury, and vascular injury (*prior anterior approaches* → adhesions of iliac vessels making retraction difficult thus increasing risk of vascular injury).

POST-OP MANAGEMENT

- begin ambulation on postoperative days 1–3 with supervised use of a walker and a simple corset when out of bed.

- 2 weeks postoperatively: isometric leg exercises, avoid excessive bending or lifting
- weeks 2-6: outpatient physical therapy, begin driving, light bending, and lifting.
- after 6 weeks: gradually resuming normal activities

OUTCOMES

- all current studies have generated a large body of evidence on the safety and efficacy of arthroplasty, and overall noninferiority to fusion.
- **ROM preservation**: ROM is reduced at 3 months after surgery and increases thereafter; at 5-year follow-up, mean ROM values are at least as much as the preoperative value.
- **adjacent level disease**: 2 randomized controlled trials showed that the difference in ASDeg becomes more significant after 5-yr follow-up* and that within 5 yr, the rates overall are similar.
  *Prodisc L decreased ALD rate 3-fold
- **index level facet joint degeneration** was higher than other levels with Prodisc at an average of 53 mo follow-up (rate of facet degeneration was significantly higher at L5-S1 level).
- **reoperation rates** were higher in the 2-level arthrodesis group at 5-yr follow-up vs. 2-level LDR.

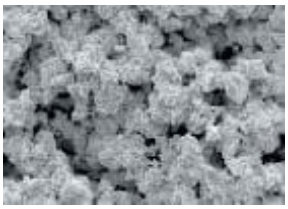
PRODISC® L (CENTINEL SPINE)

See brochure >>
Indications, requirements, contraindications – see above.

MR Conditional at 3T

- scan time of 15 minutes - maximal expected temperature rise is < 2°C
  - maximum observed heating of 1.8ºC for 1.5 T and 1.7°C for 3.0 T with a whole body averaged SAR of 2 W/ kg as assessed by calorimetry
- artifact may extend up to 5 cm from implant.

DESIGN



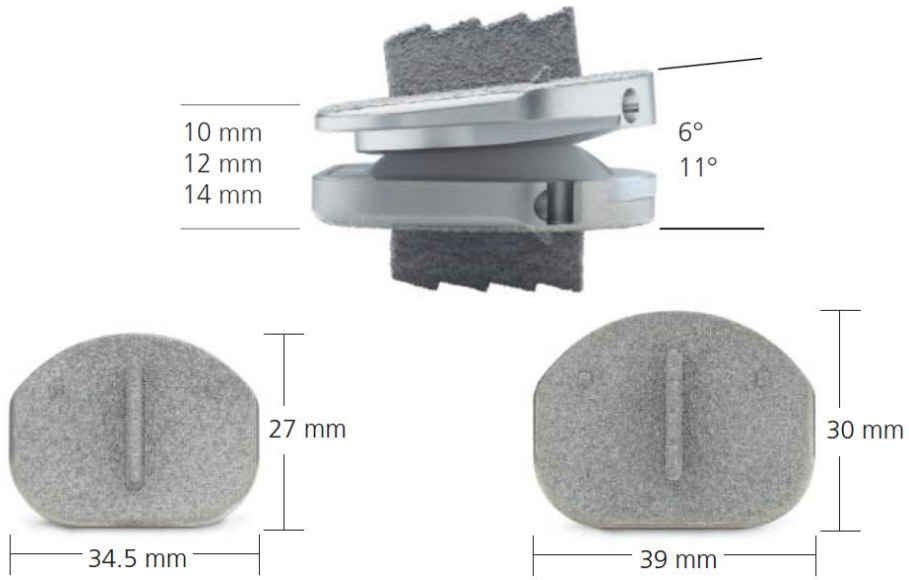
Ball and Socket:

1. Two **cobalt chrome alloy (CoCrMo) end plates**
   - central keels and small spikes.
   - plasma sprayed titanium coating on all bone-contacting surfaces to promote bony integration.
   - designed to prevent pure translational motion to theoretically protect the facets from excessive shear loading
2. **Ultra-high-molecular-weight polyethylene (UHMWPE) inlay**.

- includes a radiopaque tantalum marker (cervical Prodisc-C does not have marker).
- inlay is locked in the inferior endplate – prevents translation and, thus, load on facets! (major advantage over competitors!)

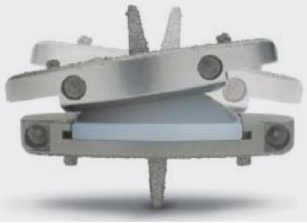
Options

- footprints: medium and large
- heights: 10, 12, 14 mm (measured posteriorly)
  10 mm is most common height (14 mm - something is not right, maybe missed spondy); always err on smaller size!
- lordotic angles: 6° and 11°

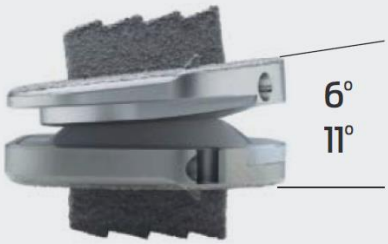


		Medium	Large
Superior Endplates 	3°	PDL-M-SP03S	PDL-L-SP03S
	6°	PDL-M-SP06S	PDL-L-SP06S
	11°	PDL-M-SP11S	PDL-L-SP11S
Polyethylene Inlays 	10 mm	PDL-M-PT10S	PDL-L-PT10S
	12 mm	PDL-M-PT12S	PDL-L-PT12S
	14 mm	PDL-M-PT14S	PDL-L-PT14S
Inferior Endplates 	0°	PDL-M-IP00S	PDL-L-IP00S
	3°	PDL-M-IP03S	PDL-L-IP03S
	8°	PDL-M-IP08S	PDL-L-IP08S

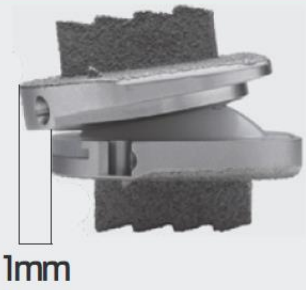
Range of Motion (All Sizes)

Flexion / Extension: 13°/7°	Lateral Bending: 10°/10°
	

Two Lordotic Angles



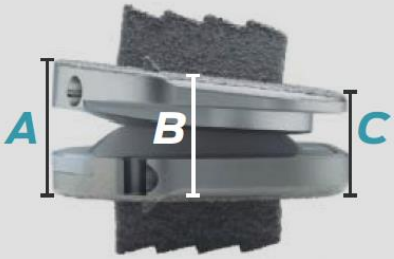
Controlled Translation



3 Implant Heights (10mm, 12mm, 14mm)

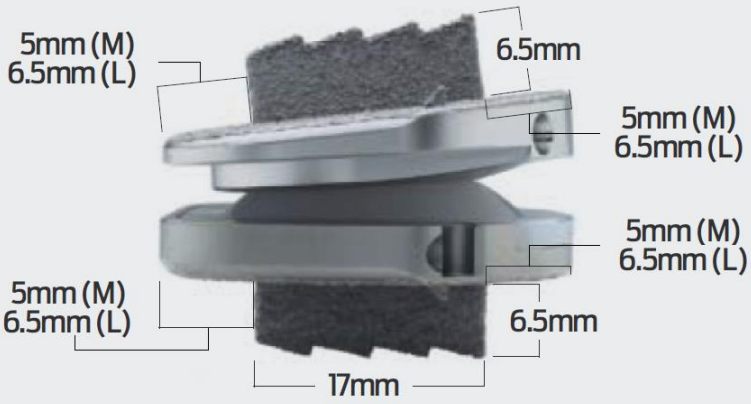
Height without Inlay (Upon Insertion)	Height with Inlay
	

Neutral Construct Heights

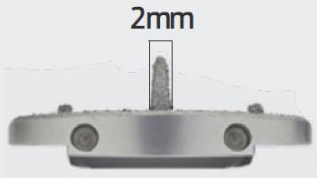


Implant Size	Anterior Height (*A*)	Central Height (*B*)	Posterior Height (*C*)
M, 6°, 10mm	12mm	11mm	10mm
M, 11°, 10mm	14.5mm	12mm	10mm
L, 6°, 10mm	12mm	11mm	10mm
L, 11°, 10mm	15mm	12mm	10mm

Keel / Tantalum Marker Dimensions

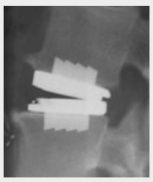


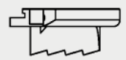
Tantalum Marker

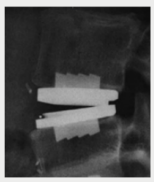


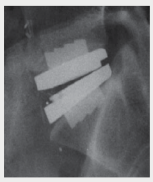
prodisc L Endplate Options

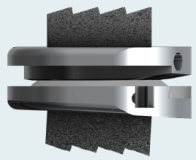
L3-L4		L4-L5		L5-S1	
6°	6° Sup / 0° Inf *Space axis in extension (above horizontal; most common)*	6°	3° Sup / 3° Inf *Space axis below horizontal*	6°	3° Sup / 3° Inf · *Low sacral slope* · *Flat back*
	3° Sup / 3° Inf *Space axis near horizontal (much less common)*		6° Sup / 0° Inf *Space near horizontal*	11°	3° Sup / 8° Inf · *High sacral slope* · *High lordosis angle*



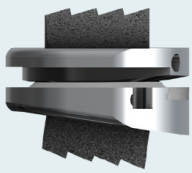








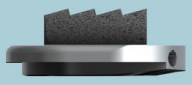
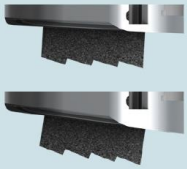
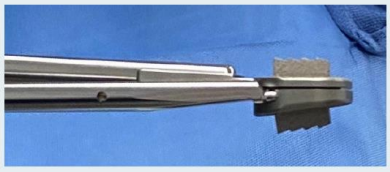
3° / 3° Construct



3° / 8° Construct

NEW ANGLED ENDPLATES FOR prodisc L

Current Endplates + New *Additional* Angled Endplates

	Current Endplates	New *Additional* Angled Endplates	
Superior Plate	Angled Plate *6° and 11°*	Flat* Plate *3°*	 *3°*
Inferior Plate	Flat Plate *0°*	Angled Plate *3° and 8°*	 *3°* *8°*
Configuration with Inserter	 prodisc L Inserter and current plates: Angle on top, flat on bottom	 prodisc L Inserter & ***new additional plates***: "Flat" on top*, angle on bottom	

* "Flat" = 3°

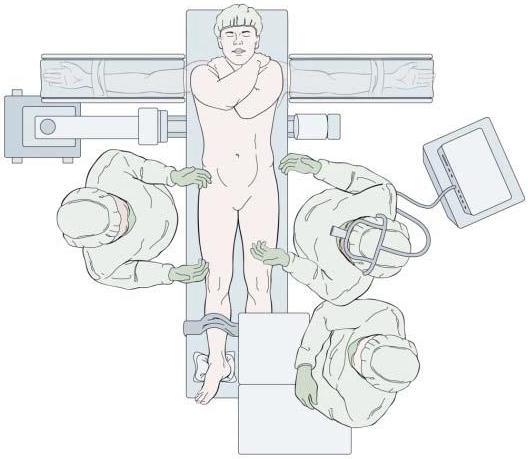
- 6 and 11 degrees are on label; other combinations are off label.
  - — 11 is only needed for L5-S1 (still trial with 6 first);
  - — for L5-S1 use lordotic plate inferiorly and more neutral superiorly – makes joint space more horizontal.

SURGERY

Also see above for the principles >>

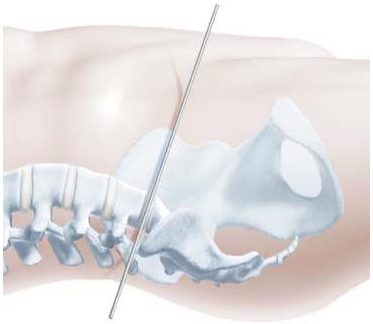
APPROACH

- **midline anterior lumbar approach** - coordinate the surgical procedure with a spinal-access trained vascular or general surgeon.
- need AP and lateral fluoroscopy throughout procedure – allow for circumferential use of C-arm.
- supine, neutral position on radiolucent operating table.
- arms abducted 90° (or adducted and crossed over chest):



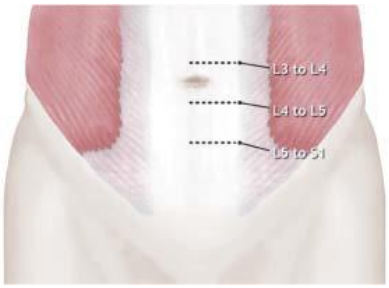
- two-level surgeries should be performed sequentially, level by level: begin with **most collapsed** disc (if both are similarly collapsed, then begin with the **caudal** level).

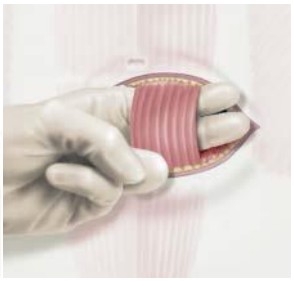
- locate correct disc level and incision by taking **lateral XR view** while holding a straight metal instrument at the side of the patient (in multi-level cases, consider the best approach needed to best access both discs):



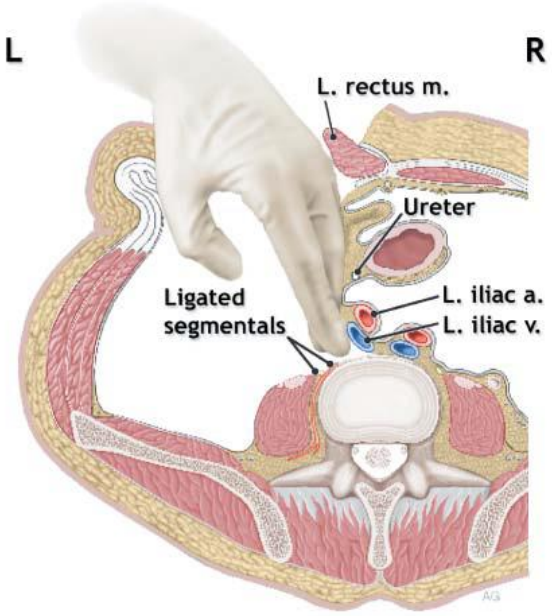
Mini-open retroperitoneal approach:

- transverse skin incision, beginning at midline and continuing laterally 5–6 cm to the left.
- incise anterior rectus sheath along the same line, extending the dissection beyond the ends of the skin incision.
- elevate anterior rectus sheath to allow for full mobilization of the rectus muscle





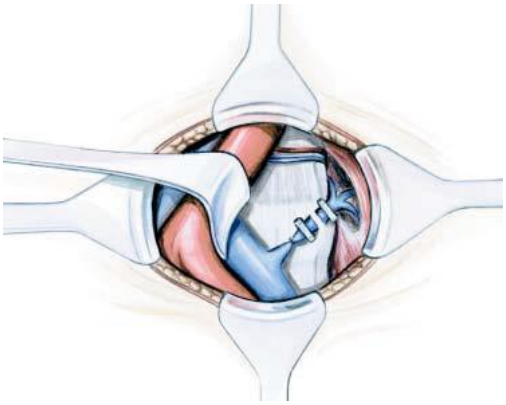
- retract the rectus muscle towards the midline.
- incise the posterior sheath vertically to the peritoneum.
- carefully push peritoneum posteriorly at the edge of the fascial incision.
- manually develop plane between peritoneum and abdominal wall, into retroperitoneal space.
- bluntly elevate peritoneum away from psoas muscle (identify ureter and lift it away with peritoneum).
- palpate medially to feel for disc, vertebral body and iliac artery.
- elevate peritoneum away in all directions to expose the disc space.



Note: Avoid tearing peritoneum (close any tears immediately before proceeding with the approach).

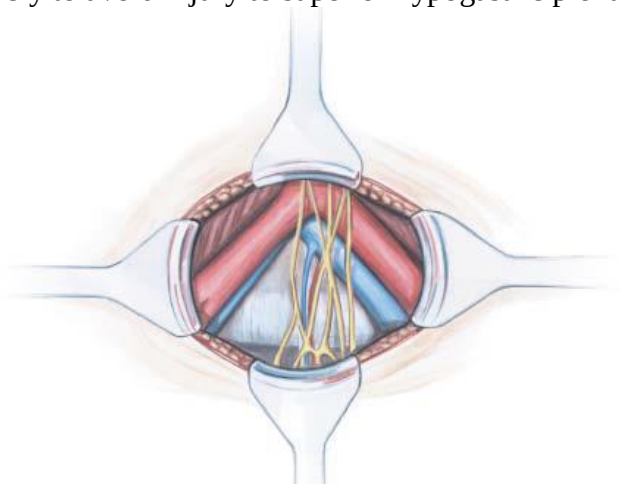
L3–L5 disc spaces - typically located posterior to the aortic and vena cava bifurcation.

- mobilize **left iliac artery**, ligate and cut **iliolumbar vein(s),** and then retract artery and vein from left to right to provide adequate exposure of disc space and vertebral bodies (Note: care must be taken to ensure the left iliac vein and artery are mobile prior to retracting)



L5–S1 disc space - typically located below the aortic and vena cava bifurcation.

- retract the left and right common iliac vessels laterally and superiorly to provide adequate exposure of the disc space and vertebral bodies.
- take middle sacral vessels to provide clear exposure of disc space (Note: use cautery cautiously to avoid injury to superior hypogastric plexus)



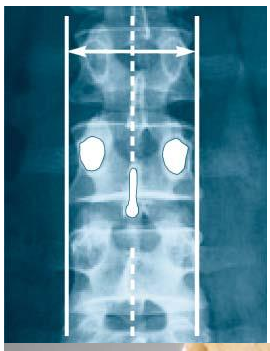
MARKING MIDLINE

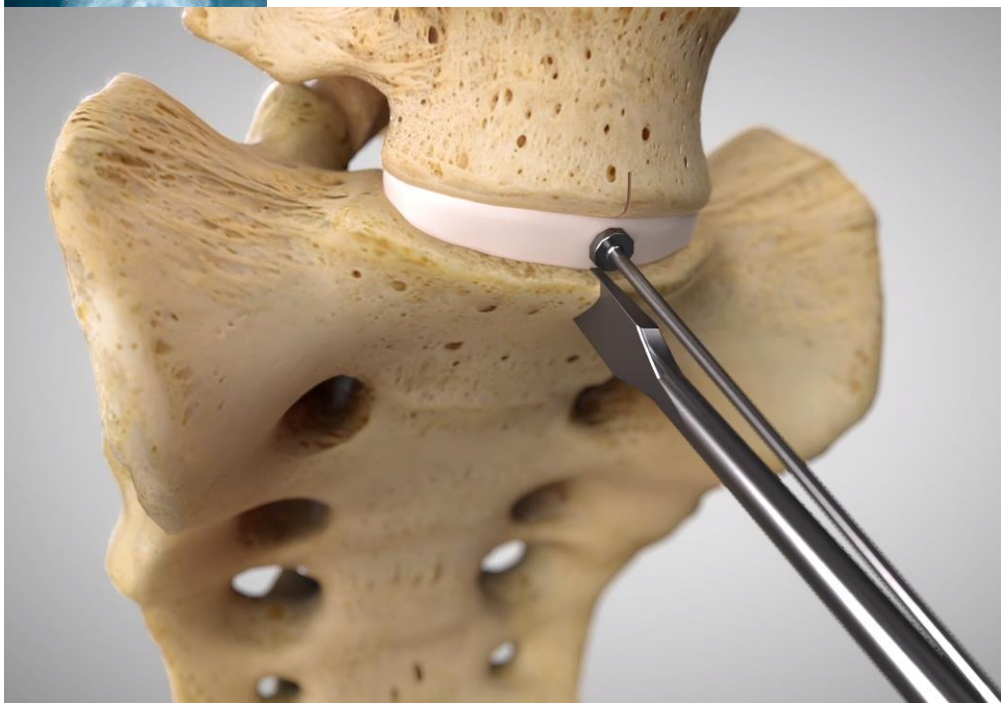
Excellent 5-minute video guide (surgical technique starts at 2:22) >>

- use AP fluoroscopy to identify midline before discectomy.
- mark midline on superior and inferior vertebral bodies so the mark remains visible throughout entire procedure.

Midline indicator:

Midline marker:

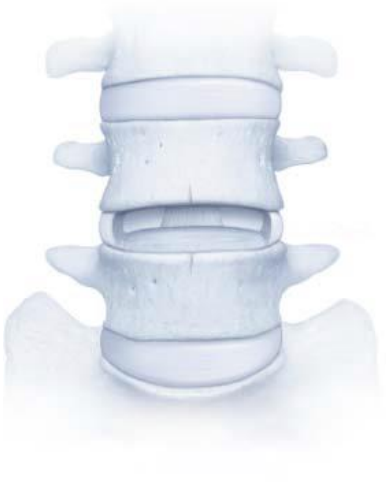




DISCECTOMY, END PLATE PREPARATION, REMOBILIZATION

- remobilize the diseased segment to restore the disc height.
- **annulotomy** centered on midline and wide enough to accommodate implant:

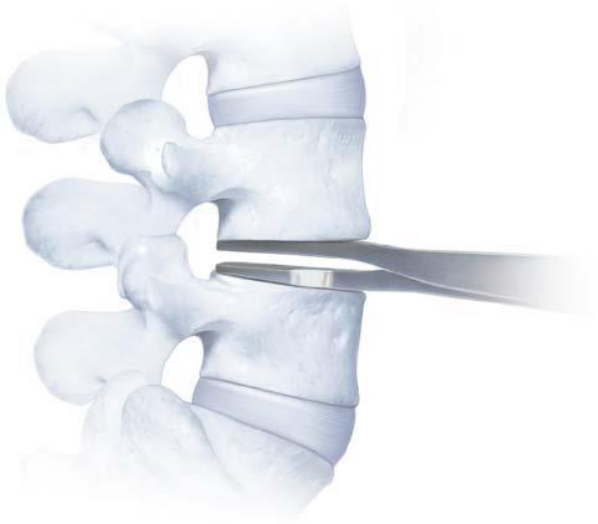
- thorough discectomy using bone elevator and standard rongeurs, Kerrisons, and curettes - ensure posterolateral corners are freed of disc material:



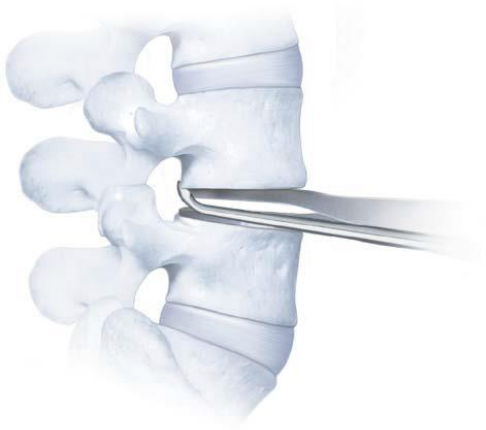
Bone Elevator:

- insert **vertebral body spreader** to posterior margin of vertebral bodies → fluoroscopy to ensure tips of vertebral body spreader are resting on posterior margin prior to distracting (to minimize risk of vertebral end plate fracture) → gradually remobilize the motion segment using parallel distraction.

Vertebral Body Spreader:



- place the spreader on one side to facilitate the discectomy on the contralateral side, and then repeat for the other side.
- remove the cartilaginous end plates to bleeding bone, taking care to not compromise the integrity of the bony end plates.
- ***posterior annulus should be completely resected*** to expose posterior longitudinal ligament (PLL) and to remobilize the segment.
- if posterior remobilization cannot be achieved, PLL may need to be released from posterior vertebral body with curved curette, transected, or completely resected:



- two vertebral body spreaders can be used to obtain balanced remobilization.

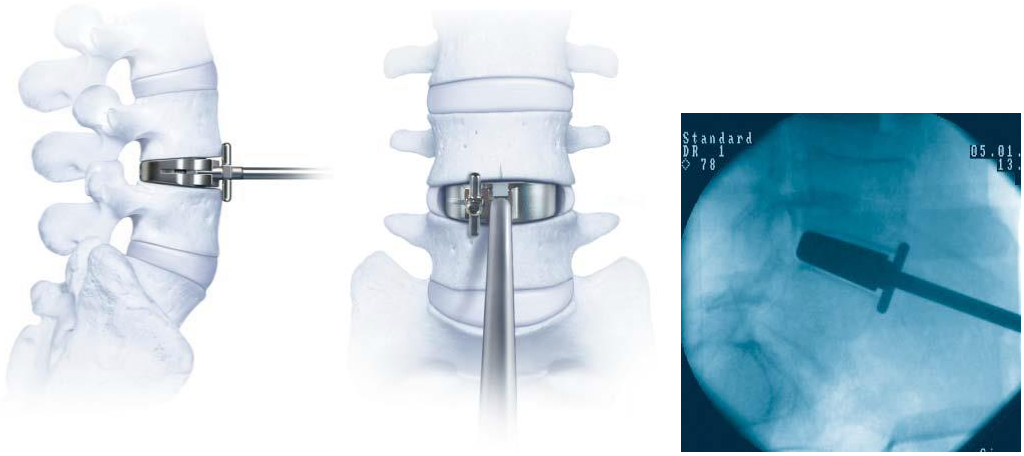
IMPLANTATION

TRIAL

- trials are placed into the disc space to determine the appropriate implant footprint, lordotic angle and disc height (select the **largest footprint** to maximize coverage of the vertebral bodies, **disc height** to match that of a normal adjacent disc space, and **lordosis** angle that matches the anatomy).
- use screwdriver to ***assemble the stop into the trial*** (ensure that the adjustable stop instrument is fully seated to the trial body).

- connect the handle to the shaft of the trial by pulling back on the flange (handle locks onto the shaft of the trial implant and can be oriented in one of four positions).

- insert the trial into the intervertebral disc space, centered on the midline mark and aligned with the sagittal plane of the vertebral body:



- under lateral fluoroscopy, advance the trial to the posterior margin of the vertebral bodies with slotted mallet.
    - stop can be backed out to allow the trial to be positioned more posteriorly (each full counterclockwise rotation of the stop allows the trial to be advanced 1 mm posterior):

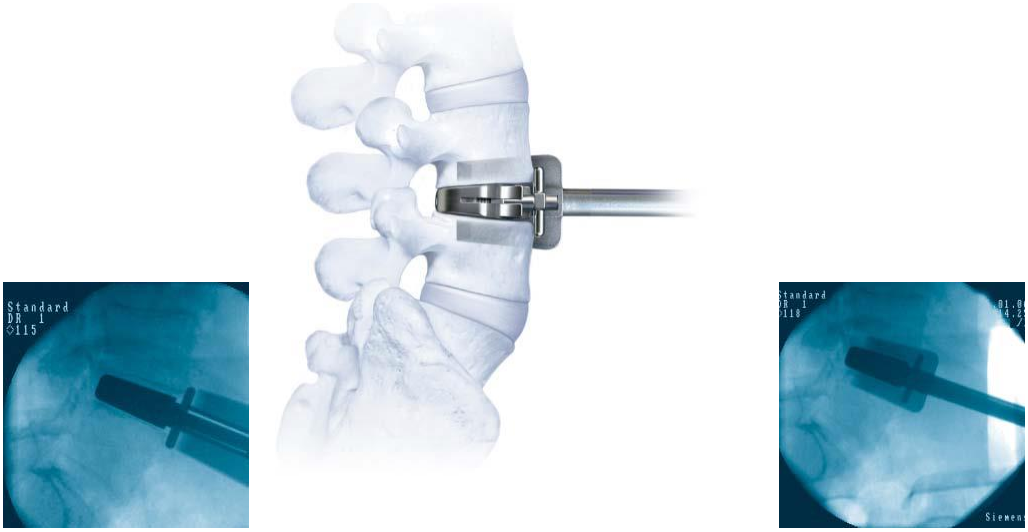
N.B. optimal position of the trial is at the **posterior margin** of the vertebral bodies, and centered on the midline!

Slotted mallet:

CHISEL

- trial is used as a jig to control the direction and depth of the chisel cuts.
  - remove the handle from the trial.
  - slide the chisel onto the shaft of the trial.

    Note: ensure that the stop on the trial is fully seated against the vertebral body prior to chiseling.
  - under lateral fluoroscopy, advance the chisel into the vertebral bodies with the slotted mallet until the chisel is fully seated on the trial (until the "stop" on the trial is reached - this will ensure that the chisel depth is adequate):

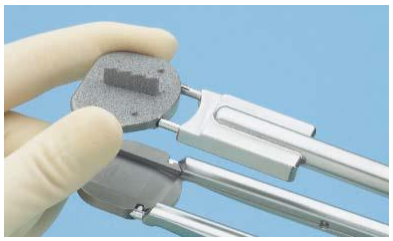


  - it may be necessary to perform <u>two chisel cuts</u> to ensure adequate chisel depth on each vertebral body: first chisel cut should follow the angle of the inferior vertebral body, then, the chisel should be cephalized so the second cut follows the angle of the superior vertebral body:

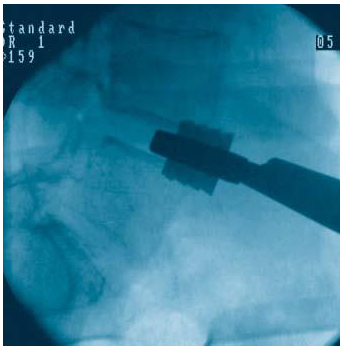
  - chisel and trial are left in place until implant is ready for insertion.

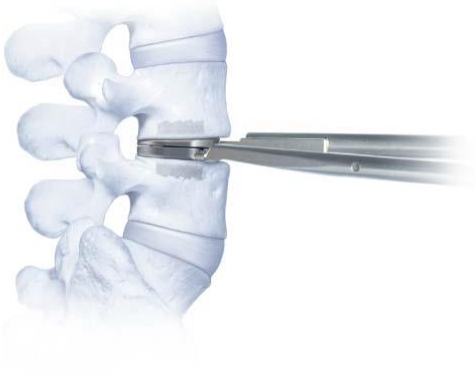
INSERTION (END PLATES)

- modular technique - implant end plates are inserted in a collapsed position and then distracted for polyethylene inlay insertion.
- press the release button on the back of the inserter and rotate the inferior arms outward → assemble the inferior end plate onto the pins of the inferior arms → press the release button and rotate the arms inward to lock the inferior end plate onto the pins → load the superior end plate onto the pins on the superior arms of the inserter → nest and hold the two end plates together by firmly gripping the inserter arms.


- remove the chisel and trial, ensure the disc space is clear of any disc or bony debris.
- align the keels of implant with the chisel cuts.
- under fluoroscopy, use slotted mallet to insert end plates to posterior margin of vertebral bodies (visually confirm that the anterior edge of the prosthesis is within the anterior edge of the vertebral body):

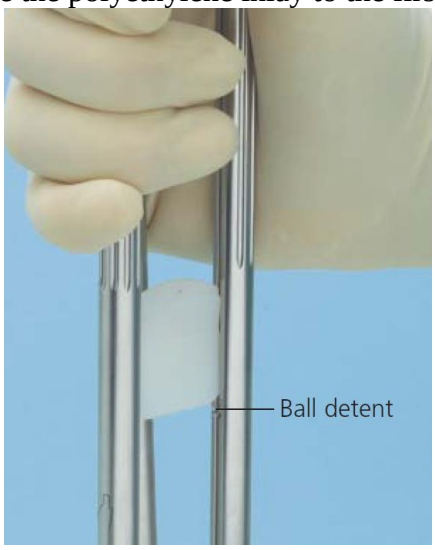




INSERTION (INLAY)

- insert the polyethylene inlay into the grooves in the inferior arms of inserter with the "Dome Up and Dome Up" (ensure that inlay is placed in the proper direction by confirming that the rounded profile is facing anterior):

- advance the polyethylene inlay to the first ball detent

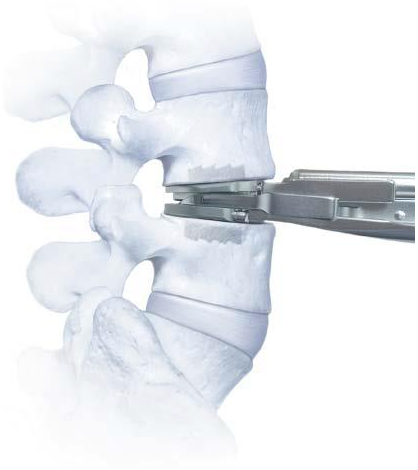


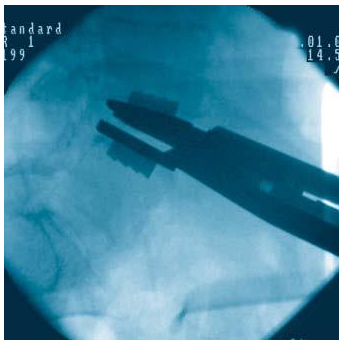
- distractor:

- assemble the distractor to the inserter:

- under fluoroscopy, use the thumbscrew to fully advance the distractor:

- verify that the posterior edge of the end plates have separated from each other (do not attempt to force and lock the polyethylene inlay if the end plates have not separated) - additional discectomy and remobilization may be required if the end plates do not separate:





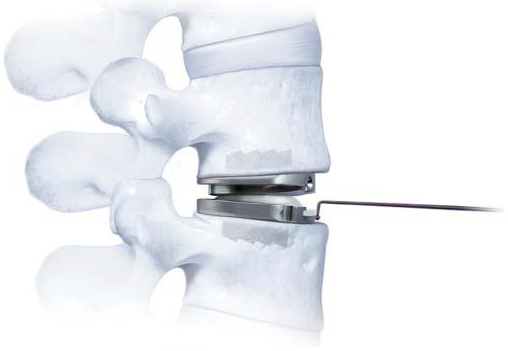
<u>Inlay is inserted and locked into the inferior end plate:</u>

Inlay pusher:

- insert the inlay pusher into the same grooves in the inferior arms:

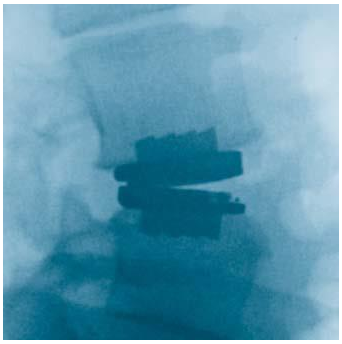
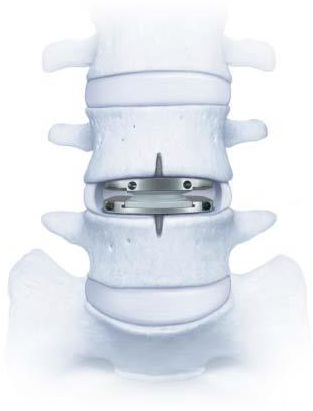
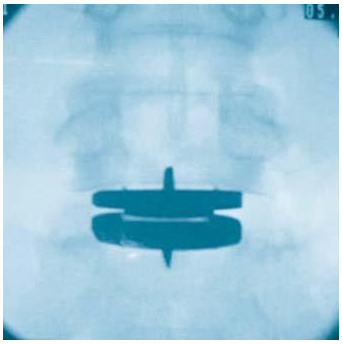
- manually push and lock the polyethylene inlay into the inferior end plate:

- remove the inlay pusher.
- visually confirm the polyethylene inlay is locked into the inferior end plate (tantalum marker does not ensure whether or not the inlay is fully seated in the inferior plate) - nerve hook may be used to verify that NO STEP and NO GAP are present at the anterior edge of the end plate:



- remove the distractor from the inserter (ensure that the polyethylene inlay is securely locked within the inferior plate component, else, anterior displacement of the polyethylene inlay will occur).
- press the release button of inserter → rotate the inferior arms outward to unlock inserter.

- verify final implant position with lateral and AP imaging:

Lever: