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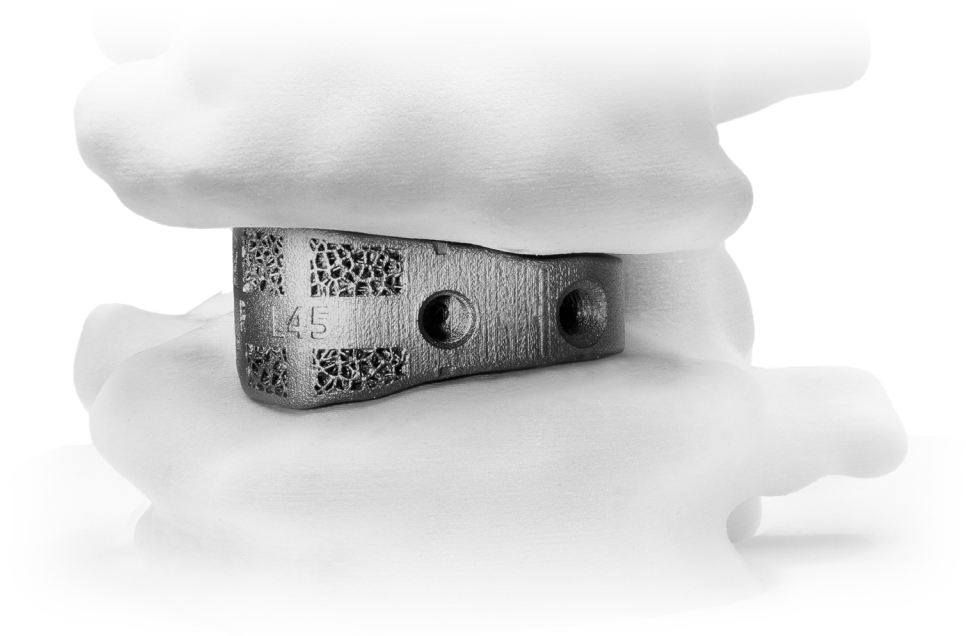

The Rationale for Personalized Interbody Devices

Literature Review

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Adult Spinal Deformity – Current and Projected Prevalence

Adult spinal deformity (ASD) affects 2 – 25% of US adults[1,2] and up to 68% of elderly.[3] At least 1.6 million US adults seek treatment each year.[4]

ASD impacts health-related quality of life more than arthritis, chronic lung disease, diabetes, and congestive heart failure.[5]

A time-series analysis was conducted by Kalakoti *et al* to forecast the US healthcare burden from ASD between 2015-2040 using 2001-2014 National Inpatient Sample epidemiological data. Projections were compared to the baseline 2014 year, showing that by 2030 and 2040, **hospital admissions for spine deformity will increase by approximately 75% and 122% from their baseline 2014 crude-admission rates.** During the same period, the rate of surgical deformity correction will outpace conservative techniques, likely witnessing **an 87.9% increase by 2030 and 143% increase by 2040 from 2014 rates.** Despite inflation-adjustment to 2018-dollar value, the cost of care for ASD will be expensive, **increasing by 48% (+$55,223 in 2030) and 76% (+$87,220 in 2040)** compared to 2014 baseline values (Figure 1).[6]

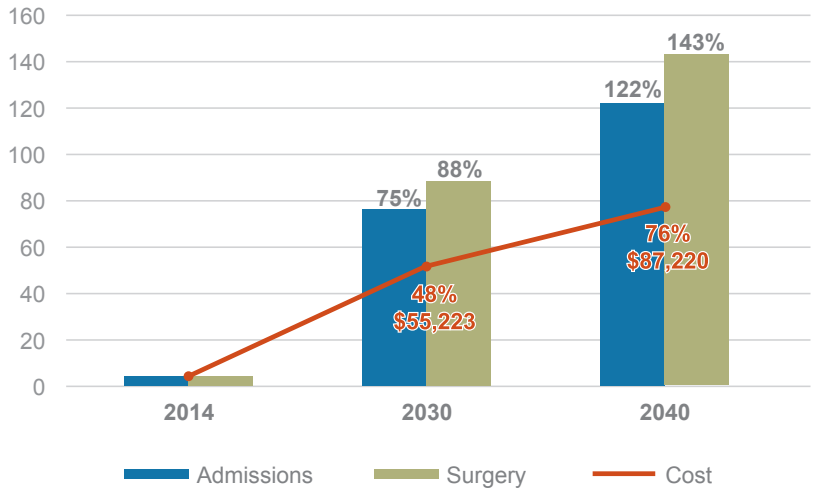


Figure 1. Percent Growth in Admissions, Surgical Procedures and Treatment Cost of Adult Spinal Deformity by 2030 and 2040 from 2014 Baseline

Incidence of Complications and Revisions

While surgical treatment has been proven to be superior to conservative care[7] the incidence of adverse events and long-term complications from surgery is extremely high.

- **Up to 75% of patients still have a radiographic deformity after surgery[8]**
- **Over 40% experience a major adverse event that is surgery or implant related[9]**
- **Over 20% require revision surgery[10]**

The average cost of one major adverse event has been documented to exceed $100,000 and require over 50 days of hospitalization.[11] The primary implant related complications necessitating revision surgery are:

1) proximal junctional kyphosis (PJK)

2) pseudoarthrosis and/or endplate subsidence at the fusion level

3) rod breakage

PJK, a pathologic problem around the segment adjacent to the fusion, has been linked to overcorrection and lordotic disproportion.[12] Pseudarthrosis, which is a failure of the vertebral bodies to fuse, is impacted by loading conditions, specifically the load distribution and contact area between the vertebral endplates and the bone graft. Endplate subsidence may lead to loss of correction as well as pseudoarthrosis. Rod failure may be the result of extreme rod bends or excessive loading over time. When the intervertebral bone fails to fuse, anatomical loads are transferred to the spinal rod exposing it to excessive loading over time and an increased likelihood of dynamic rod fracture.[13]

Glassman *et al* showed that of 122 operative patients, **at five years, 38 (31%) had a revision surgery,** three of whom had two revisions and one had three revisions (Figure 2).[14]

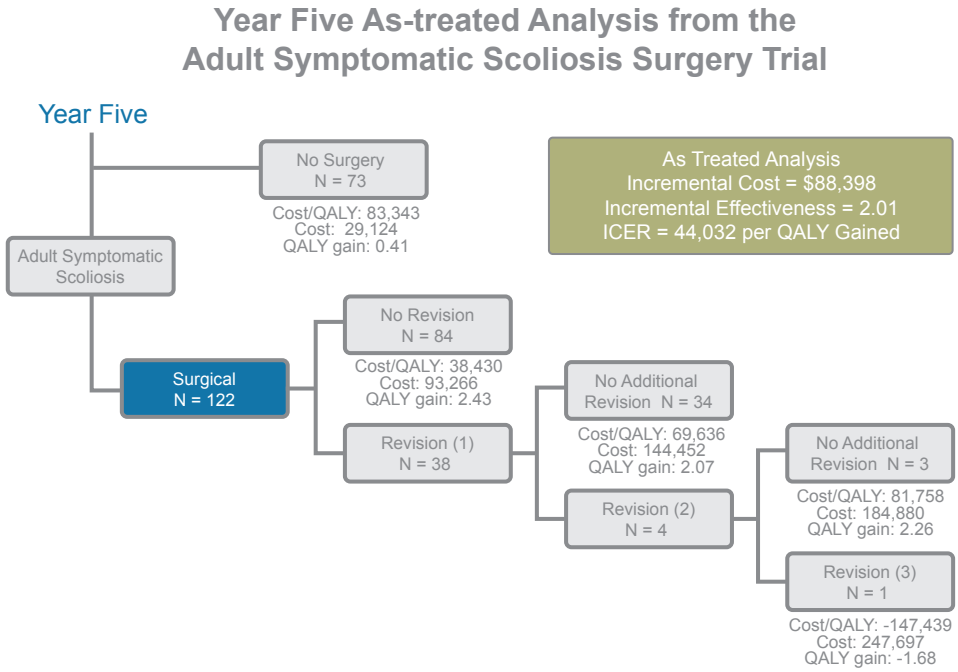


Figure 2. Flowchart of subjects in the fifth year of follow-up, 38 (31%) of patients in the Op group had a revision surgery of whom two had two revisions and one had three revisions.

In an analysis of patients at 5 years postop, Cerpa *et al* showed that **212/272 patients (77.9%) experienced an adverse event (AE) by year 5**, 20% had a severe AE; and 59% of severe AE patients required some form of surgical treatment (either revision spine surgery or other surgery). (Figure 3) Between years 2-5, 36/77 (47%) had a complication the most common being implant failure.[15]

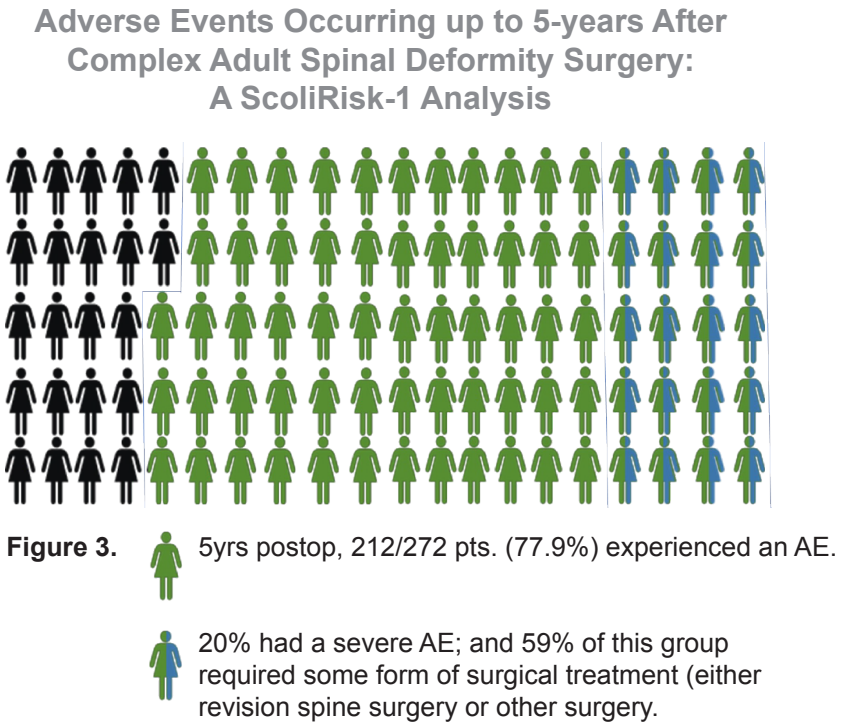


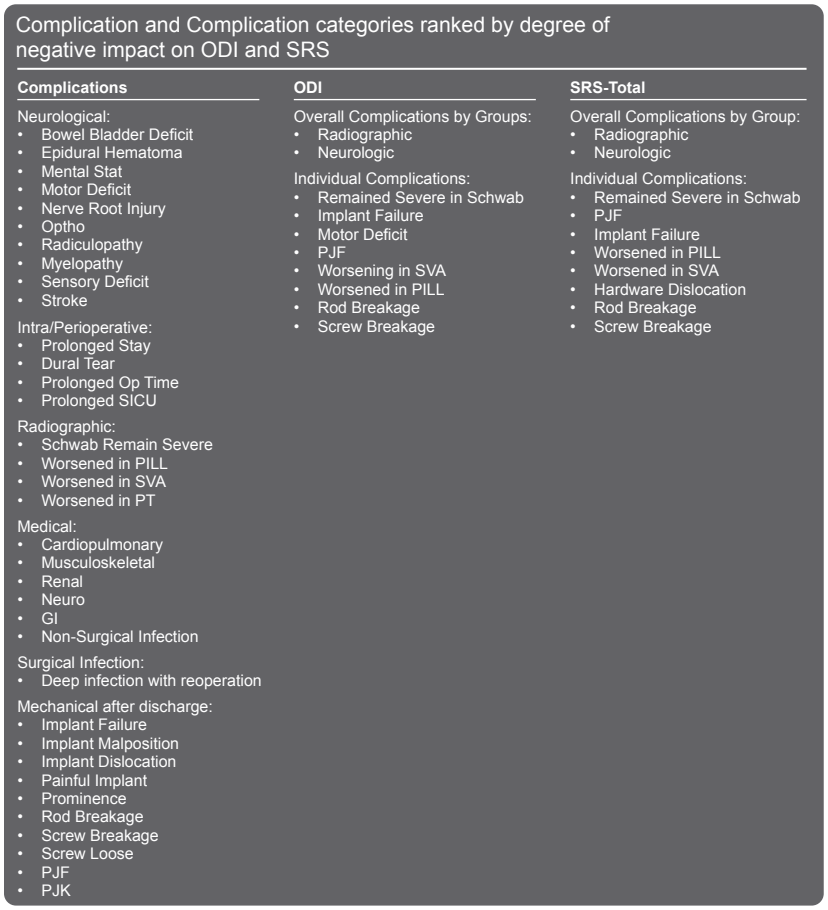
Figure 3.

The relatively high rate of complications, adverse events and revision surgery have resulted in poor long term outcomes, reduced patient satisfaction, and increased cost of care.

Alignment Matters

Radiographic malalignment has a far greater impact on clinical outcomes than perioperative and postoperative complications in ASD Surgery. In a study by Krol *et al* the authors concluded: "Despite a significant portion of patients experiencing intraoperative/perioperative, medical, mechanical, and many neurological complications, **the most detrimental contributors to poor long-term outcomes were almost exclusively related to poor radiographic correction, loss of correction post-operatively, and mechanical failure"** (Figure 4).[16]

Radiographic Malalignment Has a Far Greater Impact on Clinical Outcomes than Perioperative and Postoperative Complications in ASD Surgery



- Retrospective cohort study of 762 ASD patients.
- Complications:
  - » 317 (42%) radiographic unrelated to PJF
  - » 135 (17.7%) neurological
  - » 245 (32.2%) medical complications
  - » 545 (71.5%) mechanical after discharge
  - » 248 (32.5%) intra/perioperative
  - » 17 (2.2%) surgical infection related
- Radiographic complications had the most impact on ODI and SRS, followed by neurological complications.

Figure 4. Complication and complication categories ranked by degreee of negative impact on ODI and SRS.

In patients undergoing 1-3 level fusion for lumbar **degenerative pathology, spinopelvic malalignment has been shown to be a significant predictor of risk for revision surgery.**[12] A meta-analysis of patients who developed ASD after lumbar fusion for degenerative disease versus those who did not demonstrated **that adjacent segment degeneration patients had higher PT, lower LL, and higher PI-LL mismatch.**[17]

ASD patients with a **postoperative PI-LL mismatch have exhibited a 10-fold higher risk for revision surgery.**[12] Further, a **PI-LL mismatch of >11 degrees has a positive predictive value of 75% for the development of symptomatic adjacent level disease requiring revision surgery.**[18]

In their three-article series on adjacent segment disease and proximal junctional kyphosis, Buell *et al* identified residual **positive global sagittal malalignment as a patient risk factor for PJK/PJF**. The reported prevalence of PJK and PJF ranged from 20% to 39% and 1.4% to 35%, respectively.[19]

In the vast majority of cases, PJK and PJF occurred relatively soon after surgery with approximately 66% of cases of PJK and 80% of PJF cases occurring within 3 months after surgery.

Alignment Challenges

Schwab and Lafage showed that pre-operative planning is the greatest determinant in ensuring that post-operative alignment matches the ideal. However, the planned correction is only achieved approximately 70% of the time.[20]

In addition to appropriate surgical planning, surgeons also need the intraoperative tools that will allow the operative intervention to align with planning goals. Moal *et al* reviewed a multicenter, prospective, consecutive, surgical case series of 161 patients from the International Spine Study Group to evaluate the effectiveness of surgical treatment in restoring spinopelvic alignment. Instrumentation consisted of a combination of intervertebral body devices and supplemental fixation (posterior rods and screws). The authors found that only 23% of patients experienced complete radiographic correction of the deformity (Figure 5).[8]

Postoperative categorization

Type of curve	Thoracic	Thoracolumbar	Double	Thoracic sagittal	Thoracolumbar sagittal	Double sagittal	Sagittal	Total
No Deformity	55[6]	75(9)	38(6)	20(2)	5(2)	16(6)	14(4)	23(37)
Coronal deformity	18(2)	13(5)	25(4)	10(1)	13(5)	16(6)	0	14(23)
Sagittal deformity	18(2)	13(2)	25(4)	50(5)	45(14)	32(11)	75(17)	35(57)
Combined deformity	9(1)	0	13(2)	20(2)	37(17)	35(14)	11(7)	27(44)

Figure 5. Data are shown as patients (% [n]) falling into the following groups: no deformity (no parameters meeting deformity thresholds), coronal deformity (coronal Cobb angle and / or global coronal alignment meeting thresholds), sagittal deformity (sagittal vertical axis, pelvic tilt, and/or pelvic incidence and lumbar lordosis mismatch meeting thresholds), and combined deformity (at least 1 coronal and 1 sagittal parameter meeting thresholds) groups by Scoliosis Research Society–Schwab curve type.

One reason for failing to achieve the targeted alignment likely relates to the discrepancy between cage lordosis and achieved lordosis. Uribe *et al* conducted a radiographic study in cadavers to measure lordosis restoration after anterior longitudinal ligament release and placement of lateral hyperlordotic interbody cages during the minimally invasive lateral transpsoas approach (Figure 6).[21]

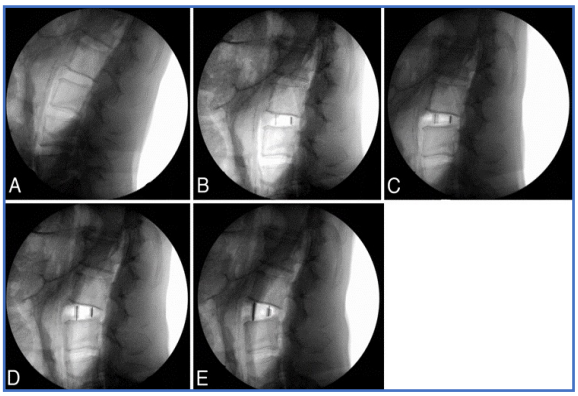


Figure 6.
Lateral fluoroscopic images showing test condition progression from preimplantation (A), 10° lordotic cage without ALL release (B), 10° lordotic cage with ALL release (C), 20° lordotic cage with ALL release (D), and 30° lordotic cage with ALL release (E)

The mean maximum increase in segmental lordosis following ALL release and placement of a 30° cage was only 11.6° (Figure 7)

	Segmental Level (º)				
Test Condition	**L1-2**	**L2-3**	**L3-4**	**L4-5**	**All Levels (º)**
10º cage	2.0 ± 1.4	0.7 ± 1.8	1.3 ± 3.0	-0.7 ± 3.1	0.9 ± 2.5
ALL release + 10º cage	4.3 ± 1.6	3.7 ± 1.9	5.4 ± 3.7	3.1 ± 2.9	4.1 ± 2.7
ALL release + 20º cage	9.1 ± 2.8	9.7 ± 2.6	9.7 ± 4.5	9.5 ± 3.5	9.5 ± 3.3
ALL release + 30º cage	11.2 ± 2.9	11.3 ± 3.1	13.1 ± 4.5	10.6 ± 3.6	11.6 ± 3.6

* Values are presented as the mean ± SD.

Figure 7. Changes in segmental lordosis from preoperative*

Further complicating efforts to achieve targeted alignment, Ozgur *et al* uniquely demonstrated that degenerative conditions often cause substantial irregularities or pits in the surface of vertebral endplates, resulting in a mismatch between the interbody cage surfaces and the vertebral endplates.[22] Unless bone is removed and the endplate surface is reshaped, a stock interbody device cannot achieve full endplate contact. Placing a stock interbody device against these voids may lead to point contact, higher stress concentration, increased risk of subsidence, suboptimal bone graft loading and unpredictable alignment. (Figure 8).

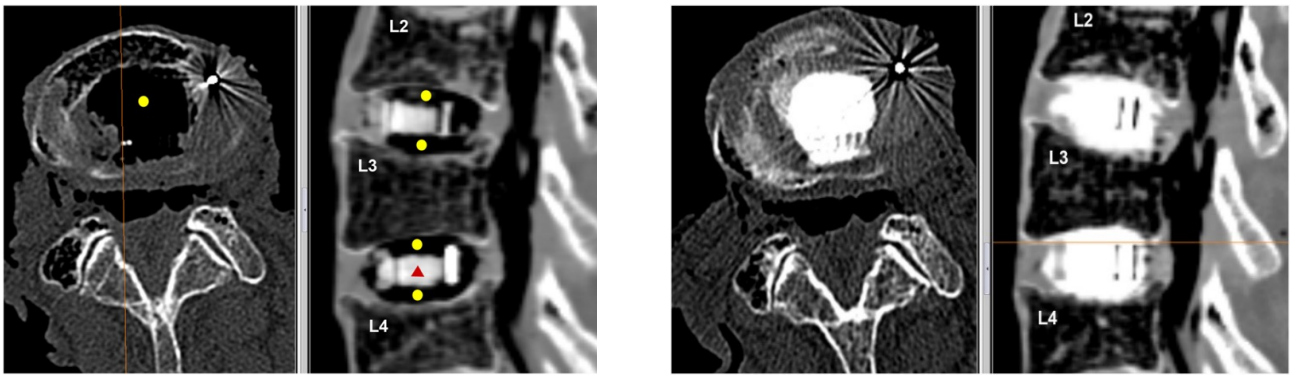


Figure 8. The gap between stock devices and endplate anatomy.

In the presence of surface irregularities, a partial removal of the endplate to improve the fit between the interbody device and bone has been tried. This technique, however, has become

less desirable with increasing knowledge of the risk factors for subsidence. Rodrigues *et al* demonstrated that, with advancing disc degeneration, vertebral endplate porosity increased between 50% and 130% and trabecular thickness decreased by between 20% and 50% ($p<0.05$). With disc degeneration, the most-dense peak moved closer to the surface and the density of this bone simultaneously decreased. The quantity of trabeculae below the transitional zone (most dense peak) also decreased as the disc became more degenerated (Figure 9).[23]

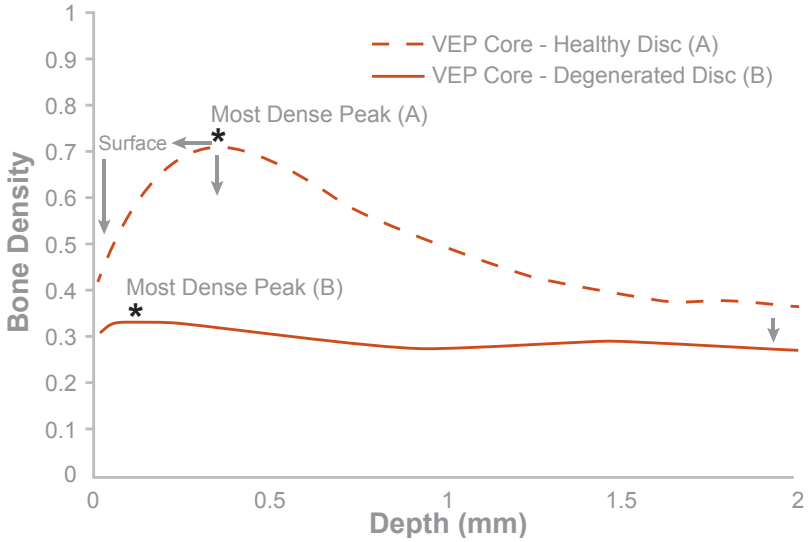


Figure 9. Degeneration changes from two representative vertebral cores: (A) adjacent to a healthy disc and (B) adjacent to a degenerative disc, are illustrated showing a bone density variation in 2 mm depth. As the disc adjacent to a vertebral endplate became more degenerated (sample B), the most-dense peak moved closer to the surface and the bone density decreased with degeneration. The quantity of trabeculae below the transitional zone (most dense peak) also decreased as the disc became more degenerated.

This data indicates that in the presence of a degenerated disc, extreme care must be taken to preserve the subchrondral bone of the endplate because its most dense peak may only be 0.1mm from the endplate surface, and the density of this bone is significantly reduced in comparison to healthy disc conditions.

Even the most cautious attempt to prepare an endplate to better fit against a stock interbody device may cause endplate injury, which can result in cage subsidence, loss of segmental lordosis and loss of foraminal height.

Lee *et al* used quantitative 1mm thin section CT to determine the contact area of fused local bone inside titanium cages in 54 consecutive patients. They studied cage to bone contact area ratios using titanium cages filled with a local bone graft for PLIF to assess the fusion rate of local bone within cages. The contact area of fused local bone inside cages is important in terms of

defining the role of cages as fusion constructs or whether they function as spacers. “The ratio of fused area of local bone inside cages at regions exposed to endplates was 50% in the present study, which is unsatisfactory.” The above data indicate that 50% of the exposed area of cages is insufficient for transmitting body weight above the fused level. Furthermore, 9.33% of cases had a fused area ratio of under 20%, and the quality of fusion observed was “hardly good enough to justify the use of the word “fusion”” (Figure 10).[24]

There is “need for a new bone bonding interbody spacer to provide a greater interfacial area”.

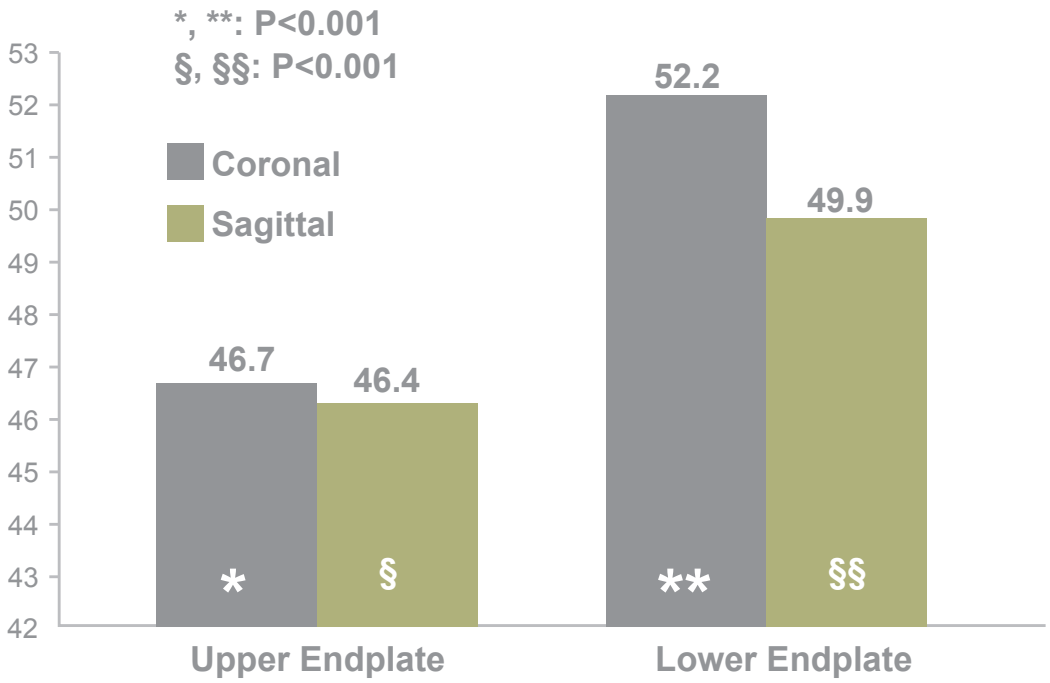


Figure 10. The ratio of fused area of local bone inside cages at regions exposed to endplates in the coronal and sagittal planes.

Personalized Interbody Cages

Patient specific interbody devices have several features that differentiate them from stock devices (Figure 11). These devices are designed to match the personalized alignment targets for each patient, including sagittal and coronal correction.

In addition to achieving the targeted alignment, the anatomical interface between the device and vertebral endplate may provide an improved environment for fusion through increased contact area, decreased points of high stress concentration, improved load distribution on bone grafts, a lower stress increase in the adjacent disc and facets, and decreased stress on posterior rods.

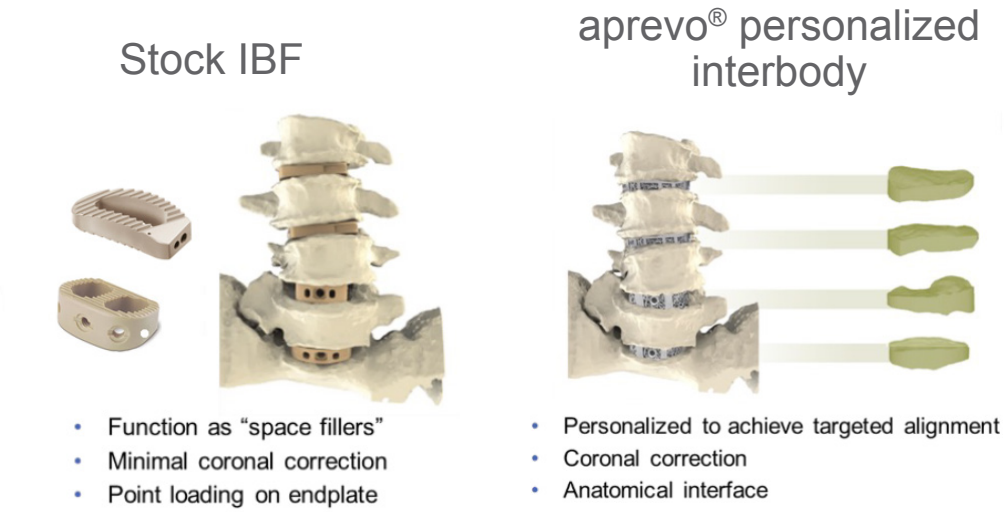


Figure 11. Key differences in design charateristics between stock interbody devices and personalized devices.

The potential advantages of personalized interbody cages have been investigated by numerous groups. These devices have been shown to improve the surgeon's ability to achieve the targeted alignment. In addition, the feature of an anatomical interface (Figure 12) provides several meaningful attributes relative to load distribution. These attributes provide a direct benefit as it relates to the most common causes of implant related complications (Figure 13).

Figure 12.
The fit of a stock interbody device against the endplate (left) is compared to the fit of a personalized device (right).

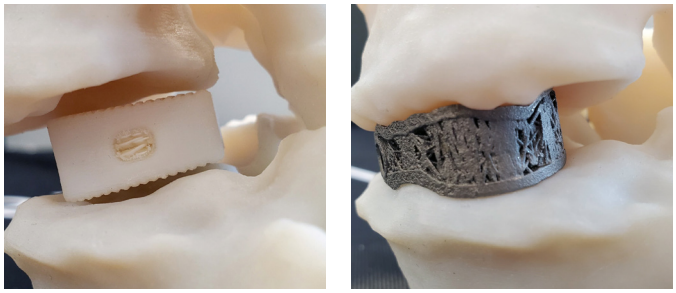


Figure 13. Common complications related to the surgical treatment of adult spinal deformity (left); frequently described contributing factors (center); and potential characteristics of personalized interbody devices (right).

Clinical case examples of personalized interbody devices are shown in the following figures. Figures 14, 15 and 16 depict device placement through anterior, lateral and transforaminal approaches, respectively. These examples demonstrate the typical endplate irregularities caused by degenerative conditions. The endplate matched contour of the personalized interbody device provides an improved fit against the endplate surface. (Note - the below images are for demonstration purposes only and no patient health information is shown.)

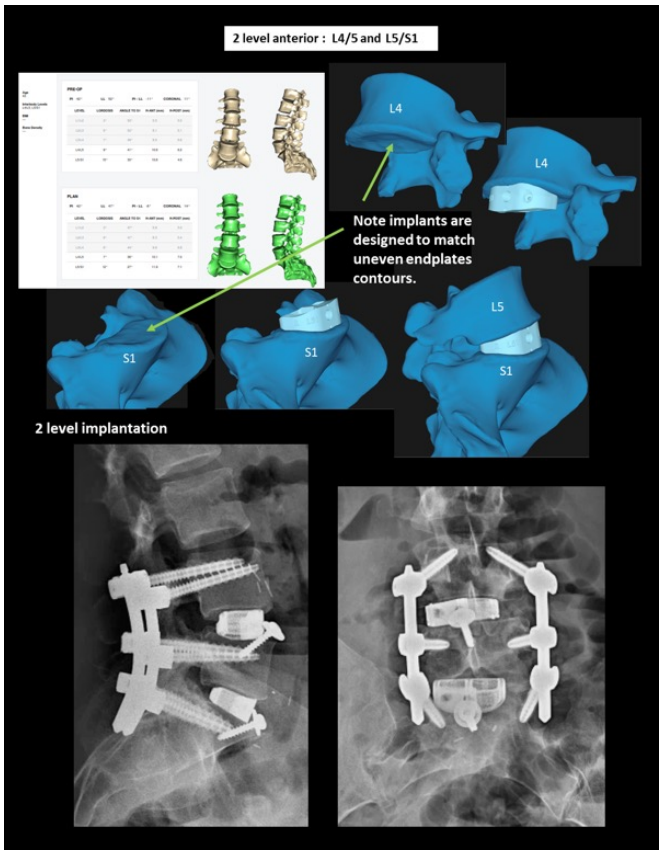


Figure 14. Two level ALIF example of endplate conforming implant and personalized geometry to match desired correction plan.

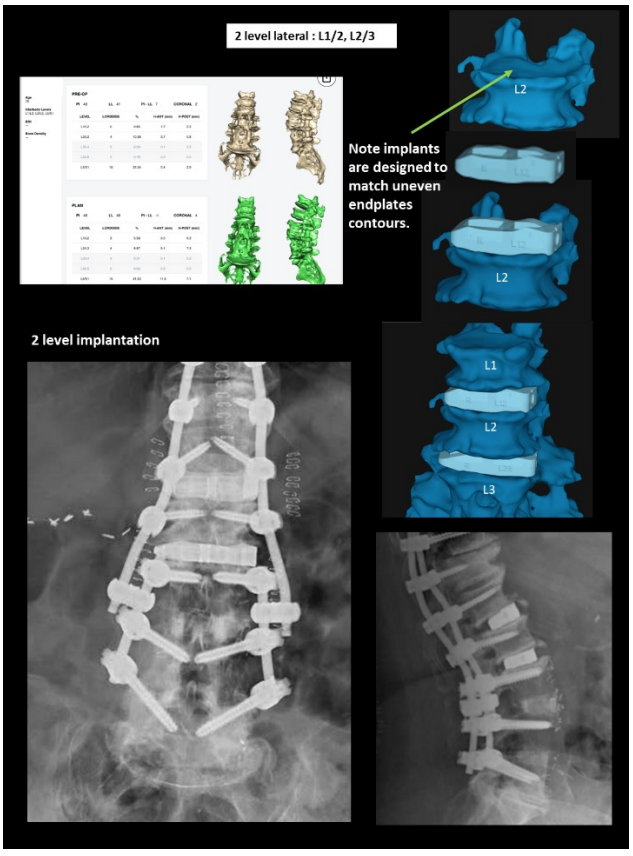


Figure 15. Two level LLIF example of endplate conforming implant and personalized geometry to match desired correction plan.

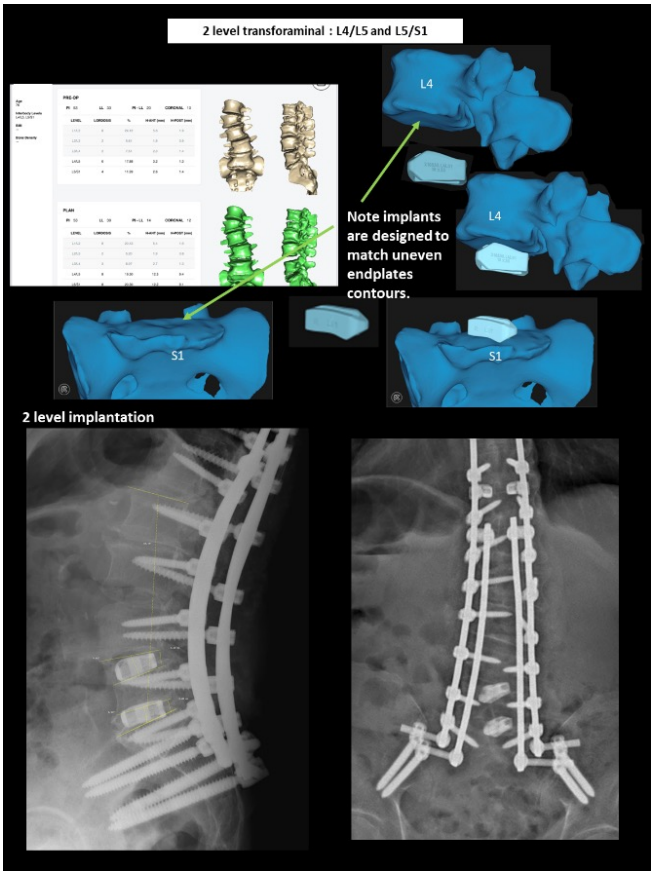
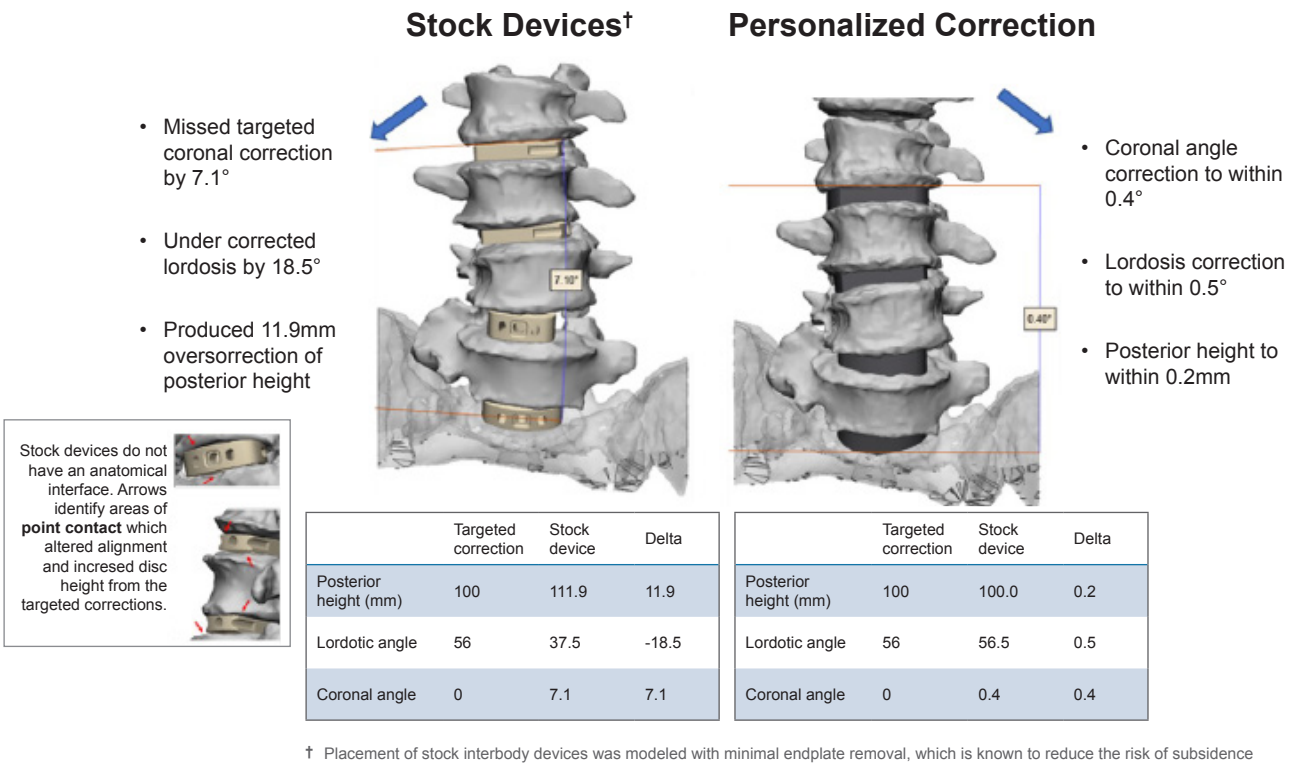


Figure 16. Two level TLIF example of endplate conforming implant and personalized geometry to match desired correction plan.

Achieve Targeted Correction

In a cadaveric laboratory study comparing achieved correction versus planned correction between patient specific interbody devices and stock devices, the patient specific interbody devices demonstrated minimal difference between planned and achieved correction. The patient specific devices corrected the coronal angle to 0.4°, produced lordosis of 56.5° (versus the 56° target) and produced a posterior height of 100.2mm (versus the 100mm target). Alternatively, stock implants failed to achieve the target coronal correction; provided significantly less lordosis than targeted (37.5° vs. 56°); and produced an over correction of posterior height of 11.9mm (111.9mm versus the target of 100mm) (Figure 17).[25]



	Targeted correction	Stock device	Delta
Posterior height (mm)	100	111.9	11.9
Lordotic angle	56	37.5	-18.5
Coronal angle	0	7.1	7.1

	Targeted correction	Stock device	Delta
Posterior height (mm)	100	100.0	0.2
Lordotic angle	56	56.5	0.5
Coronal angle	0	0.4	0.4

† Placement of stock interbody devices was modeled with minimal endplate removal, which is known to reduce the risk of subsidence

Figure 17. Cadaveric comparison of achieved versus planned correction between patient specific interbody devices and stock devices.

Reduced Endplate / Rod Stress and Improved Load Distribution

Chatham *et al* used finite element modeling to compare a standard spacer to an endplate conforming spacer, to determine if a custom fit would reduce stress on the endplates. The effects of spacer material on the stress and strain in the lumbar spine after interbody fusion with posterior instrumentation were also investigated, using PEEK, titanium, poly(para-phenylene) (PPP), and porous PPP (70% by volume). Experimental testing of a cadaveric specimen was used to validate the model's results (Figures 18,19).[26]

Among implant materials,

1. **There were no large differences in stress levels (<3%) at the bone–spacer interfaces and the rods when PEEK was used instead of titanium.**
2. The **endplate conforming spacer significantly decreased (>37%) the stress** at the bone–spacer interfaces for all materials tested.
3. The **endplate conforming spacer decreased stress in the posterior rods by 28%.**
4. The endplate conforming spacer provided a greater contact area between the spacer and bone, which distributed the stress more evenly, highlighting a possible strategy to decrease the risk of subsidence.

They concluded that patient-specific spacer geometry could decrease stresses on posterior instrumentation and reduce stress concentrations in the endplates after lumbar interbody fusion.

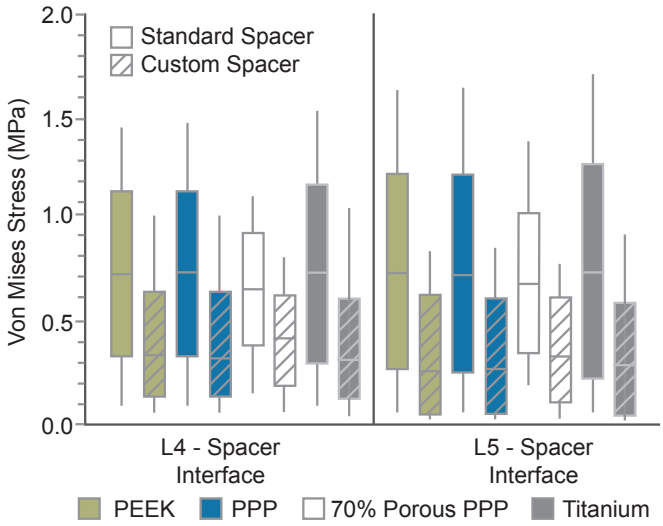


Figure 18.
Box-and-whisker plots of endplate stress distributions at the bone–spacer interfaces with the standard and endplate conforming (custom) spacer.

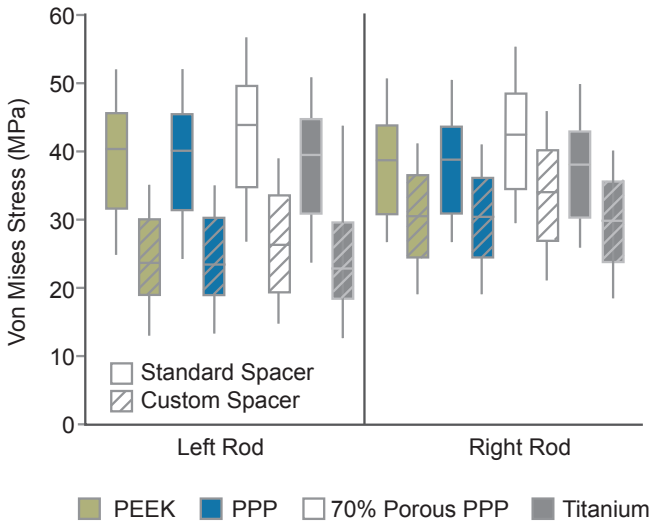


Figure 19.
Box-and-whisker plots of the stress distribution in posterior rods with the standard spacer and endplate conforming (custom) spacer.

An FEA study by Patel (Figure 20) showed differences between conforming and non-conforming ALIF cages:

1. The **conformed implant provided greater than a 50-fold increase in contact area** (3.61 mm^2 to 188.7 mm^2) resulting in a large reduction in endplate stress of approximately 50%.

2. **Material variation for a given implant geometry created negligible reductions in average endplate stress** in the case of implants with an available surface contact area greater than 50 mm^2.
3. Areas **of high stress concentrations between 30 to 150 Mpa were measured with non-conforming** ALIF cages.
4. **Endplate conformed ALIF cages created stress concentrations below 5 MPa** ranging from 2 to 3 MPa across the endplate surface.

The conclusions of this research were:

- **"The use of conformed implants is the most effective method for reducing endplate stresses and, as a result, decreasing the risk of subsidence."**
- **"Varying material properties for a single implant type did not strongly affect endplate stress."**
- **"Future implants should focus on providing a more contoured surface to match the endplate geometry, maximizing endplate contact to reduce subsidence."**[27]

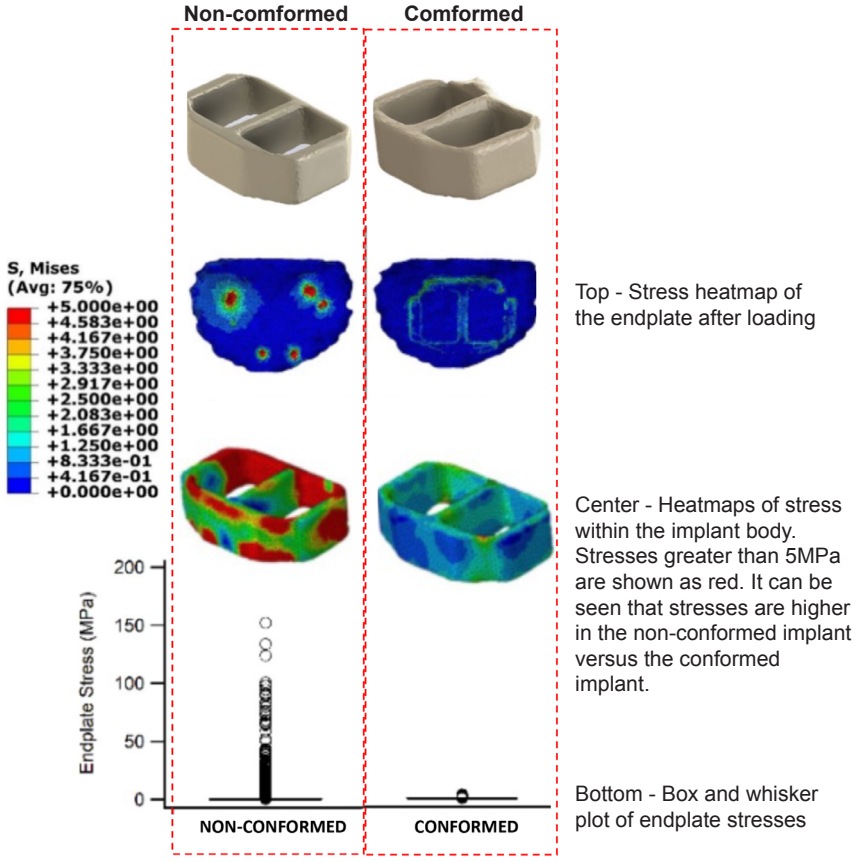


Figure 20.

A validated FEA study of 4 spinal loading conditions by Wang *et al* showed (Figure 21):

1. Anatomical interfacing design generates **75% less stress concentration** compared to a flat design, with **45% more effective contact,** more uniform stress distribution and less stress concentration.
2. The topological fitting at the interfacing surfaces of an anatomical design can offer **better performance in terms of reducing the possibility of subsidence in the long run.**
3. In addition, the **endplate conforming interbody device demonstrated improved load distribution** of the bone graft under all four loading conditions.[28]

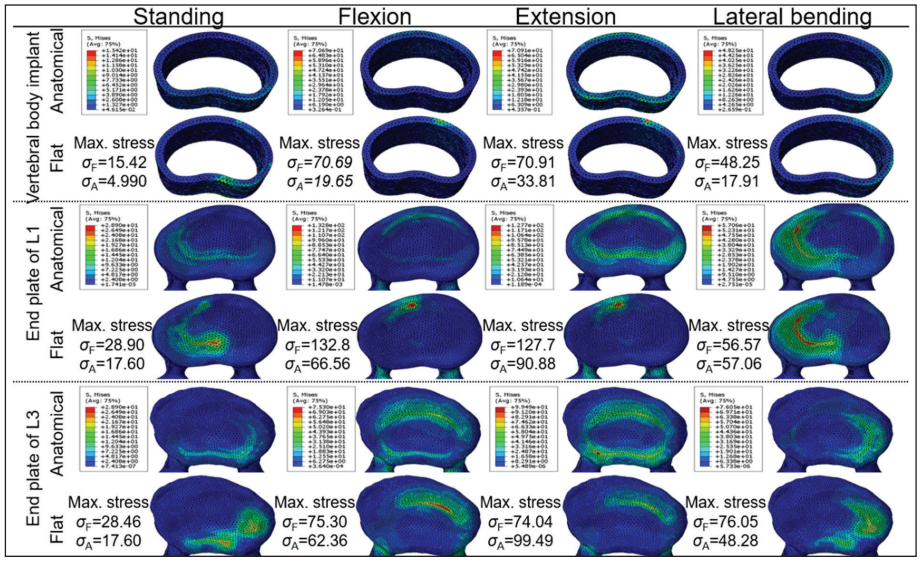


Figure 21.
Von Mises stresses predicted for the vertebral body implant, the bottom endplate of L1 and the upper endplate of L3 are compared for the flat and anatomical surface designs when under four loading conditions (σF and σA stand for maximum von Mises stress for the flat design and the anatomical design).

Zhang *et al* evaluated endplate-conformed cages in both a finite element model and cadaveric study to determine if a patient matched cage can decrease cage-endplate interface stress and increase stability in comparison to a stock (non-conformed) cage. The finite element model showed:

1. **A reduction in stress ranging from 31% - 66%** on the C4 inferior endplate with the patient matched implant and a **reduction in stress ranging from 35% - 69%** on the C5 superior endplate (Figure 22).
2. Von mises endplate stress contours, as recorded by film sensors, were markedly reduced for the endplate conformed cage (Figure 23).

In cadaveric testing, stress on the surface of the C5 superior endplate was significantly reduced in FLE (P = 0.045), EXT (P = 0.025), LB (P = 0.031) and AR (P = 0.014) (Figure 24).[29]

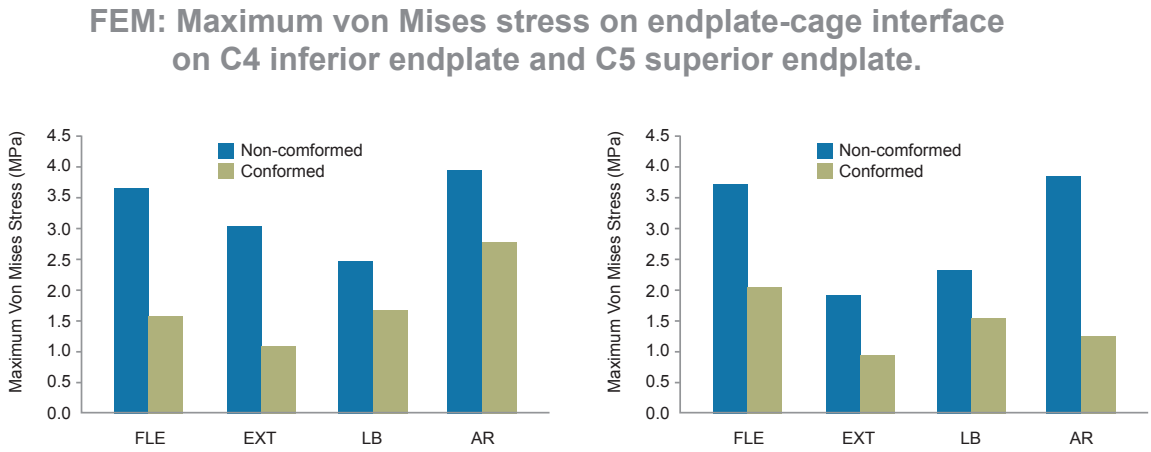


Figure 22. FEM: Maximum vonMises stress on endplate-cage interface on C4 inferior endplate (left) and C5 superior endplate (right).

Figure 23.
Comparison of Von Mises endplate stress contours between anatomical and stock devices on C4 inferior endplate and C5 superior endplate. Stress signal was recorded by the film sensor in the interface between the inferior surface of the cage and superior endplate of C5.

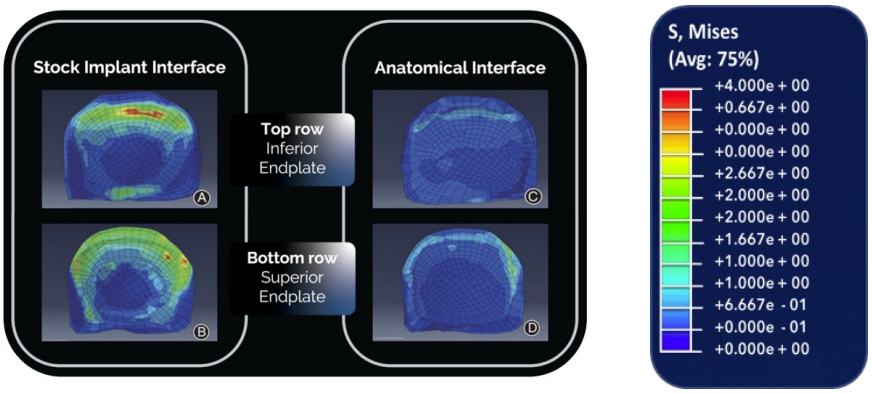
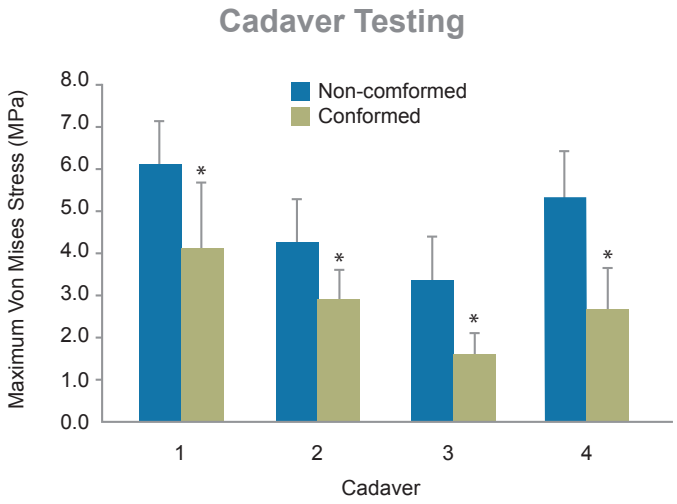


Figure 24.
Cadaver study: Maximum von Mises stress on endplate-cage interface of C5 superior endplate: stress on the surface of the C5 superior endplate is significantly reduced in FLE (P = 0.045), EXT (P = 0.025), LB (P = 0.031) and AR (P = 0.014).



A biomechanical study by Suh *et al* looked at the influence of substrate density, footprint, fill, surface texture, and material on the magnitude of subsidence in cervical interbody cages.

Commercially available cervical interbody cages of two sizes (16 x 12 mm and 17 x 14 mm) were implanted between foam blocks of two different densities and were cyclically loaded. Cages were made of Ti4Al6V, Si3N4, or PEEK (n = 8 cages of each material type) (Figure 25).

Their data showed:

- Density of substrate foam had the greatest influence on subsidence, followed by cage footprint. **Cage material had no effect on subsidence.**
- **Substrate density (bone quality) had 1.7 times greater contribution than cage footprint and 67 times greater than the contributions of material.**
- **The contribution of cage footprint area to subsidence was found to be 40 times greater than the contribution of cage material to subsidence.**

They concluded, material composition did not affect subsidence, even though the materials tested had a 100-fold difference in the modulus of elasticity, stating: "These findings suggest that the area of contact between cage and bone is relevant."[30]

Even with 100-fold difference in cage modulus, physiologically relevant loading is not achieved. Cage material had no effect on subsidence.

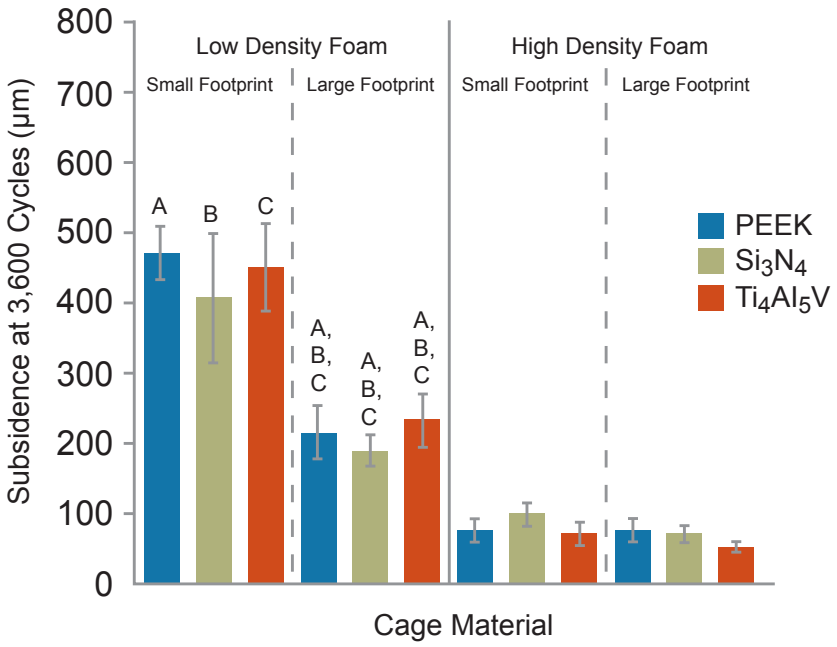


Figure 25.
Bar graph depicting subsidence at 3,600 cycles of loading with 50 to 250 N of compression. Data are means; error bars indicate standard deviation. Paired letters A, B, and C indicate statistically significant differences (P ≤0.01). Statistically significant differences in subsidence were also observed between all lower-density foam samples and their corresponding higher-density foam samples for both cage sizes and all cage materials (P ≤0.01).

Increased Contact Area

Wang *et al* applied a finite element analysis to compare the percentage of effective contact area for contributing to the bone ingrowth in standing, flexion, extension and lateral bending between an anatomically fitting and flat vertebral body implant. In standing and lateral bending, the differences in effective contact were negligible, however, in flexion, the % of effective contact for the **anatomically fitting device was 69.5% versus 47.9% for the flat device.** In extension, the **% of effective contact for the anatomically fitting device was 73.6% versus 23.7% for the flat device** (Figure 26).[28]

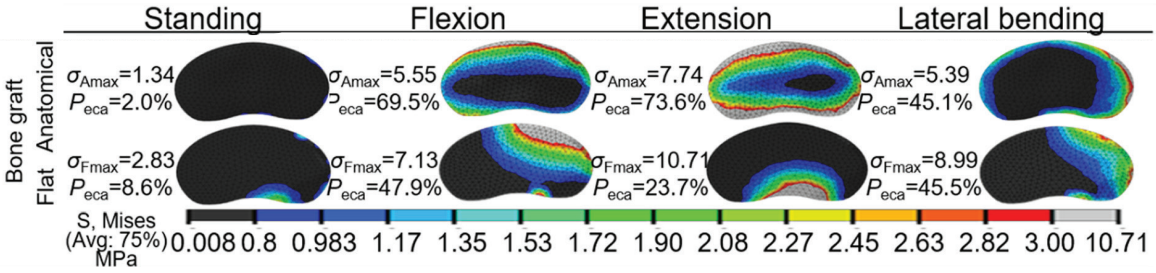


Figure 26. Von Mises stresses predicted for the bone graft comparing flat and anatomical surface designs under four loading conditions; *σFmax* and *σAmax* stand for the maximum von Mises stress on the bone graft for the flat design and the anatomical design; *Peca* denotes the percentage of effective contact area for contributing to the bone ingrowth.

Lower Stress Increase on Adjacent Level

Zhang *et al* used their previously described validated finite element model to also determine the effect of a patient matched cage on the adjacent segments. The intra-disc stresses at the C3–4 (supra-jacent) level and the C5–6 (infra-jacent) level shows that **the conformed interbody devices had intra-disc and facet loading that was closer to the intact values than the non-conformed interbody devices. This reduced increase with conforming interbody devices was recorded for all directions of motion.**

Compared to the non-conformed group, the conformed group provided approximately a 23-90% decrease in stress on the infra-jacent disc (Figure 27) and a 33-75% decrease in stress on the supra-adjacent disc (Figure 28). This data indicates that endplate-conformed cages may, to a degree, prevent the development of adjacent segment degeneration.[29]

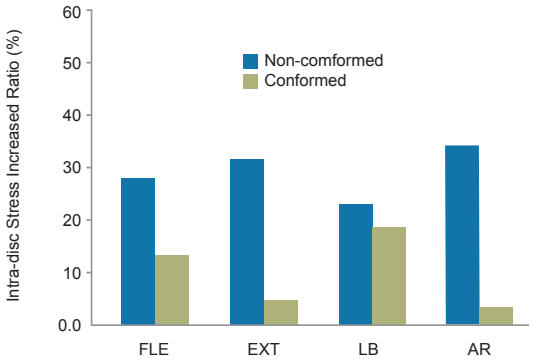


Figure 27. C5-6 Infra-jacent Level % Increase in Intra-disc Stress Versus Intact.

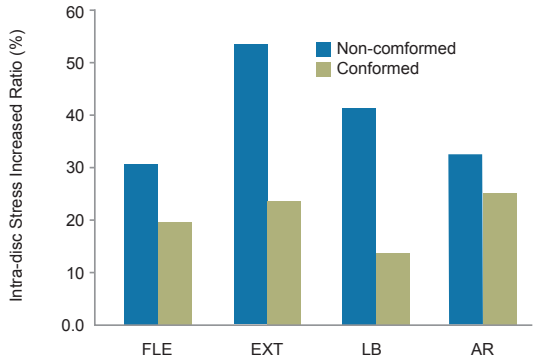
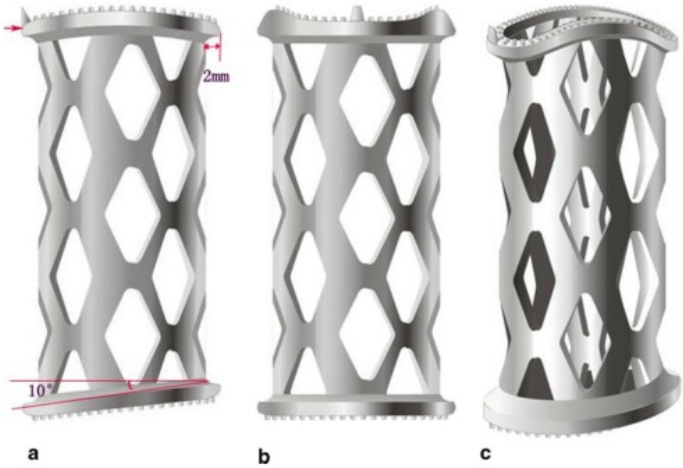


Figure 28. C3-4 Supra-jacent Level % Increase in Intra-disc Stress Versus Intact.

Reduced Subsidence and Subsidence Related Pain

Finally, Yu *et al*, performed a clinical study comparing long-term clinical results in cervical corpectomy/fusion patients receiving either a cage with partial endplate conformance or a cage with no endplate conformance (Figure 29). Fifty-eight consecutive patients were treated with a single-level ACCF using either a conforming Ti mesh cage (28 patients, group A) or a traditional Ti mesh cage (30 patients, group B) (Figure 30). Patients were evaluated for cage subsidence, cervical lordosis (C2–C7 Cobb and Cobb of fused segments) and fusion status for a minimum of 30 months postoperatively based on spine radiographs. Neurologic outcomes were evaluated using the Japanese Ortho. Assoc. scores. Neck pain was evaluated using a 10-point visual analog scale (VAS).

Figure 29.
a. Lateral image of conforming cage. Red arrow reflects its curved superior endcap. Opposite end shows inferior endcap which tilts backward and upward with an angle of 10°. Short red line reflects 2 mm of the endcap border exceeding the edge of cylindrical body. b, c. anteroposterior and oblique views of the conforming cage.



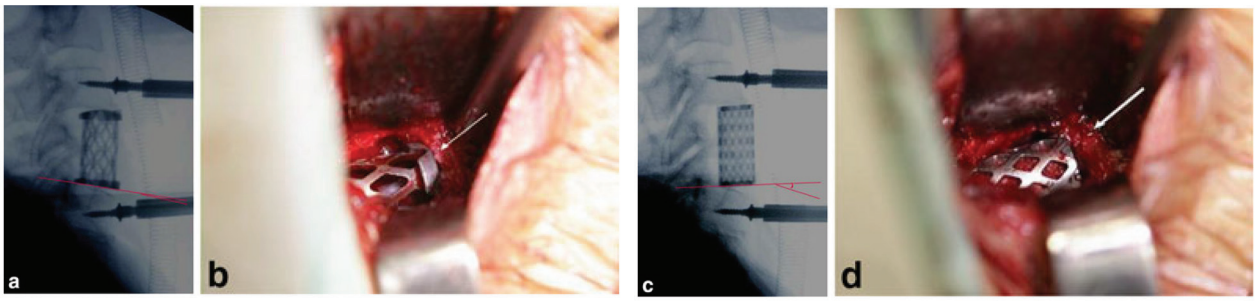


Figure 30. a, b. Intraoperative fluoroscopy and operative picture in one patient with conforming cage showed a close contact between the endcaps and the endplates. c, d. Intraoperative fluoroscopy and operative pictures in another patient with traditional cage showed a poor match between the endcaps and the endplates.

Results

- **Height loss in fused segments was less for the conforming cage versus the stock cage (0.8 ± 0.3 vs. 2.8 ± 0.4 mm) ($p < 0.01$).**
- **The conforming cage group had a lower rate of severe subsidence (4 %, 1/28) than the stock cage group (17 %, 5/30) ($p < 0.01$).**
- There were no differences in the C2–C7 Cobb and Cobb of fused segments between the groups preoperatively or at final follow-up ($p > 0.05$), but the Cobb of fused segments immediately postoperative were significantly less for the stock cages than for the conforming cages ($p < 0.01$).
- All patients had successful fusion (100 %, each). Both groups had marked improvement in the JOA score after operation ($p < 0.01$), with no significant differences in the JOA recovery ratio ($p > 0.05$).
- **The postoperative VAS neck pain scores for the conforming cage group were significantly less than that for the stock cage group ($p < 0.05$); severe subsidence was correlated with neck pain**.

The endplate conforming cage provided comparable clinical results and fusion rates in comparison to the traditional cage for patients undergoing single-level corpectomy but with decreased postoperative subsidence and a lower severity of subsidence-related neck pain in follow-up.[31]

CONCLUSION

A combination of clinical and non-clinical evidence has demonstrated that personalized interbody devices have the potential to provide meaningful benefits related to achieving the planned alignment, reducing endplate and adjacent level stress, providing increased contact area for bone graft loading and lower posterior rod stress.

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IMPORTANT PRODUCT INFORMATION

aprevo® Intervertebral Body Fusion Device

DESCRIPTION

The aprevo® intervertebral body fusion devices are designed to stabilize the lumbar spinal column and facilitate fusion. The personalized aprevo® devices incorporate patient-specific features to allow the surgeon to tailor the deformity correction to the individual needs of the patient. The aprevo® devices are made from Titanium Alloy (Ti-6Al-4V) and have a cavity intended for the packing of bone graft. The aprevo® devices are fabricated in a variety of heights, widths and anterior-posterior (A-P) lengths and may incorporate lordotic and/or coronal angulation.

INDICATIONS FOR USE

Caution: For product sold in the USA: Federal Law (USA) restricts this device to sale by or on the order of a physician.

The aprevo® anterior lumbar interbody fusion and aprevo® lateral lumbar interbody fusion devices are intended for interbody fusion in skeletally mature patients and are to be used with supplemental fixation instrumentation cleared for use in the lumbar spine. The aprevo® anterior lumbar interbody fusion and aprevo® lateral lumbar interbody fusion devices are indicated for use as an adjunct to fusion at one or more levels of the lumbar spine in patients having an ODI >40 and diagnosed with severe symptomatic adult spinal deformity (ASD) conditions. These patients should have had six months of non-operative treatment. The devices are intended to be used with autograft and/or allogenic bone graft comprised of cancellous and/or cortico-cancellous bone graft. These implants may be implanted via a variety of open or minimally invasive approaches. These approaches may include anterior lumbar interbody fusion or lateral lumbar interbody fusion.

The aprevo® transforaminal interbody device is intended for interbody fusion in skeletally mature patients and is to be used with supplemental fixation instrumentation cleared for use in the lumbar spine. The aprevo® Personalized Interbody device is indicated for use as an adjunct to fusion at one or more levels of the lumbar spine in patients having an ODI >40 and diagnosed with severe symptomatic adult spinal deformity (ASD) conditions. These patients should have had six months of non- operative treatment.

The device is intended to be used with autograft and/or allogenic bone graft comprised of cancellous and/or cortico-cancellous bone graft. These implants may be implanted via a variety of open or minimally invasive approaches.

The aprevo® implant is provided sterile and requires no further preparation before use. The aprevo® implant has been sterilized by Gamma Irradiation. An insertion instrument is provided sterile and requires no further preparation before use. The aprevo® insertion instrument utilizes a standard M5 x 0.8 thread. Before using the aprevo® device for the first time, the surgeon should be thoroughly familiar with the aprevo® Surgical Technique Guide (available upon request) as well as the functionality and assembly of the device. Lack of experience or expertise with these implants may result in complications.

The aprevo® personalized devices are fabricated to match a patient-specific pre-operative plan that is developed using the patient's radiological images. If more than six months has passed since images were acquired, or the anatomy or condition of the intervertebral space has changed since the radiological images were acquired, the patient-specific aprevo® device should not be used. The surgeon should refer to the Surgical Technique Guide for instructions regarding disc space preparation, device positioning and fit confirmation of the aprevo® device.

STERILE R — The aprevo implant is provided sterile and requires no further preparation before use. The aprevo implant has been sterilized by Gamma Irradiation.

STERILE R — An insertion instrument is provided sterile and requires no further preparation before use. The aprevo insertion instrument utilizes a standard M5 x 0.8 thread.

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POST-OPERATIVE PATIENT CARE

Postoperative external immobilization (e.g., bracing or casting) is recommended, at the surgeon's discretion. The patient should be encouraged to ambulate as soon as possible following surgery, while limiting lifting and twisting motions and any type of sports activities until the bone is healed.

STORAGE

Sterile packaged implants should be stored at ambient temperatures in a clean dry area that prevents damage to the implant packaging.

WARRANTY

Carlsmed, Inc. products are guaranteed to be free of defects in workmanship and materials when used properly for its intended purpose. Any product delivered from Carlsmed proving to be defective will be replaced or repaired, at Carlsmed's discretion, at no charge to the customer. These warranties shall not apply to conditions or defects resulting from, but not limited to: negligence, improper use, improper care and handling, improper opening techniques, unauthorized repair work, caustic or abrasive cleaners, or items modified or customized by the customer.

CUSTOMER SERVICE

For further information regarding the aprevo® device, or for a copy of the aprevo® Surgical Technique Guide, please contact Carlsmed, Inc. or your local aprevo® device distributor.

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SYMBOLS

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LOT	Lot number
	Use by
STERILE R	Sterlized using irradiation
	Do not resterilize
	Single use
	Do not use if package is damaged
	Consult instructions for use

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