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Int J Spine Surg 2016, 10 ()
doi: https://doi.org/10.14444/3024
https://www.ijssurgery.com/content/10/24

The International Journal of Spine Surgery
2397 Waterbury Circle, Suite 1,
Aurora, IL 60504, Phone: +1-630-375-1432

Cervical Disc Arthroplasty with Prestige LP Disc Versus Anterior Cervical Discectomy and Fusion: Seven-Year Outcomes

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Abstract

Background

Cervical disc arthroplasty (CDA) has emerged as an alternative to anterior cervical discectomy and fusion (ACDF) for the treatment of cervical pathologies. Studies are on-going to assess the long term outcomes of CDA. This study assessed the safety and efficacy of the Prestige® LP Disc at 84-months follow up.

Methods

Prospective data from 280 CDA patients with single-level cervical disc disease with radiculopathy or myelopathy were compared with 265 historical control ACDF patients. Clinical and radiographic follow up was completed preoperatively, intraoperatively, and at intervals up to 84 months.

Results

Follow-up rate was 75.9% for CDA and 70.0% for ACDF patients. Statistical improvements ($p<0.001$) in Neck Disability Index (NDI), neck/arm pain, and SF-36 were achieved by 1.5 months in both groups and maintained through 84 months. At 84 months, 86.1% of CDA versus 80.1% of ACDF patients achieved NDI success, (≥15-point improvement over baseline). Mean NDI score improvements exceeded 30 points in both groups. SF-36 PCS/MCS mean improvements were 13.1±11.9/8.2±12.3 points for CDA and 10.7±11.8/8.3±13.6 points for ACDF. Neurological success was 92.8% for CDA and 79.7% for ACDF patients. The rate of Overall Success was 74.9% for CDA and 63.2% for ACDF. At 84 months, 17.5% of CDA and 16.6% of ACDF patients had a possibly implant- or implant-surgical procedure-related adverse event. Eighteen (6.4%) CDA and 29 (10.9%) ACDF patients had a second surgery at the index level. In CDA patients, mean angular motion at the target level was maintained at 24 (7.5°) and 84 (6.9°) months. Bridging bone was reported in 5.9%/9.5%/10.2%/13.0% of CDA patients at 24/36/60/84 months. Change in mean preoperative angulation of the adjacent segment above/below the index level was1.06±4.39/1.25±4.06 for CDA and (-0.23)±5.37/1.25±5.07 for ACDF patients. At 84 months, 90.9% of CDA and 85.6% of ACDF patients were satisfied with the results of their treatment.

Conclusions

Prestige LP maintained significantly improved clinical outcomes and segmental motion; statistical superiority of CDA was concluded for overall success.

This investigational device exemption study was sponsored by Medtronic Spinal and Biologics, Memphis, TN. Study approved by the Hughston Sports Medicine Center Institutional Review Board on January 7, 2005. Clinical trial registered at clinicaltrials.gov: NCT00667459. All participants signed an informed consent.

KEYWORDS: CERVICAL DISC ARTHROPLASTY, ANTERIOR CERVICAL DISCECTOMY AND FUSION, ARTIFICIAL CERVICAL DISC, CERVICAL RADICULOPATHY, CERVICAL MYELOPATHY, ADJACENT LEVEL DISEASE

VOLUME 10 ARTICLE 24 DOI: 10.14444/3024

Introduction

Seven cervical disc arthroplasty (CDA) devices have now been approved by the U.S. Food and Drug Administration (FDA) for the treatment of symptomatic cervical degenerative disc disease (DDD). Twenty-

DOI: 10.14444/3024

four-month Investigational Device Exemption (IDE) studies have revealed CDA outcomes to be at least comparable to anterior cervical discectomy and fusion (ACDF).[1-6] More recently, longer-term evidence has been published for many of these same devices, demonstrating the continued safety and efficacy of CDA for appropriately selected patients.[7-11]

Decompression of the neural elements and permanent stabilization of the cervical spine through ACDF is an effective treatment for surgical candidates suffering intractable neck pain and/or increasing neurological deficit. Cervical disc arthroplasty has the potential to maintain anatomic disc space height, normal segmental lordosis, and physiologic motion patterns after surgery. Widely reported complications, which gave rise to the initial interest in cervical artificial disc replacement as an alternative to fusion, continue to be a concern worthy of exploration in these and other long-term studies.[12-21]

This study was undertaken to investigate the long-term safety and efficacy of the Prestige® LP Disc (Medtronic Spinal and Biologics, Memphis, TN). The FDA-approved Prestige LP disc is an unconstrained ball-in-trough, metal-on-metal articulation composed of a titanium ceramic composite (Figure 1). The early 24-month clinical and radiographic outcomes for this device have been reported previously.[22] We report the 7-year data from the FDA IDE study in patients undergoing single-level anterior cervical discectomy and disc arthroplasty with the cervical disc implant and compare them with those in patients undergoing single-level ACDF.

Methods

Study Design

This prospective multicenter study was conducted under an approved FDA IDE. Patients in the original 24-month study (clinicaltrials.gov: NCT00667459) were consented after institutional review board approval and followed in this FDA-regulated study for an additional 5 years.

From January to November 2005, 280 nonrandomized patients were enrolled at 20 investigational sites and received treatment for single-level cervical degenerative disc disease using a low-profile cervical disc arthroplasty device. The safety and efficacy outcomes for these patients were compared with data from the 265 historical control patients from a previous FDA-approved IDE study (IDE #G010188; clinicaltrials.gov: NCT00642876) with identical inclusion-exclusion criteria who underwent anterior cervical discectomy and fusion with allograft bone and an anterior plate, utilizing a similar surgical approach. Patients in the study were evaluated preoperatively, intraoperatively, and at routine postoperative intervals of 1.5, 3, 6, 12, 24, 36, 60 and 84 months. Adverse events and secondary surgical procedures were recorded at each follow-up interval.

Independent Data Review

As with the publication of the 24-month results,[22] the study sponsor delivered the entire database of raw data to independent biostatisticians at Vanderbilt University for analysis. Using the FDA-approved methods from the original statistical plan, analysis by the independent team that is presented in this report reached the same statistical conclusions as the study sponsor's analysis. Statisticians for the sponsor used the statistical software SAS (SAS Institute, Cary NC) to generate the summary tables and WinBUGS to conduct the Bayesian analysis. Independent statisticians at Vanderbilt used R software for the summary tables and JAGS to conduct the Bayesian analysis.

Statistical Analysis

Bayesian statistical methods are increasingly evident in the peer-reviewed literature for spinal device tri-

Fig. 1. The Prestige LP Cervical Disc.

als.[1,6] Bayesian results are "positive" when, for example, the posterior probability of efficacy ≥ 0.95 (in the more commonly used and more familiar Frequentist approach, evidence for efficacy is generally thought to be provided by p≤0.05). For assessing study data, the Bayesian posterior probability of a statement ("Treatment A tends to be better than Treatment B") is the probability that the statement is true. Furthermore, 95% Bayesian Credible Intervals (BCI) are provided for study parameters of interest. A detailed discussion of the statistical analysis plan is presented in the publication of 24-month outcomes.[22] In addition, time-to-event analysis was performed for adverse events and secondary surgery events using a Cox proportional hazards model with adjustment for propensity score.

Clinical Outcome Measures

Patient-reported clinical outcomes were measured using validated instruments including Neck Disability Index (NDI) and the 36-Item Medical Outcomes Study Short-Form Health Survey[23] (SF-36); Neck pain and arm pain numeric rating scales (duration 0-10 multiplied by intensity 0-10, adapted in part from McDowell et al.),[24] neurological status, patient satisfaction, and work status were also assessed. Patient examinations were conducted preoperatively and immediately after surgery, and self-reported outcomes questionnaires were completed before surgery and at each postoperative follow-up interval.

The primary clinical outcome measure for this study was Overall Success, a composite measure consisting of all of the following conditions: 1) NDI Success, defined as NDI score improvement of at least 15 points; 2) Neurological Success, defined as maintenance or improvement in neurological status; 3) Functional Spinal Unit (FSU) Success, defined as maintenance or improvement in disc height and no evidence of subsidence; 4) no serious adverse event (AE) classified as implant or implant/surgical procedure associated; and 5) no secondary surgical procedure classified as a "failure" (Table 1).

FSU Success was an FDA-mandated component of Overall Success, but the measurement was frequently difficult or impossible to obtain due to visualization hindrances on radiographic images of both investigational and control patients, in which case those patients were excluded from the Overall Success analysis. For this reason, Overall Success results are presented both with and without FSU Success as a component.

Radiographic Assessment

Plain radiographs were obtained preoperatively, intraoperatively, and at 1.5, 3, 6, 12, 24, 36, 60, and 84 months to characterize the radiographic measurement of the investigational device and to assess fusion success in the control group. Two independent radiologists from the core lab were trained and performed radiographic assessment measurements utilizing an orthopaedic reading system and digitized images of plain radiographs. A third independent reviewer adjudicated conflicting findings.

Using vertebral endplate distances to measure disc height was expected to be difficult due to visualization challenges created by the CDA implant, despite being low profile. Formation of a solid fusion mass can also potentially obscure measurement landmarks after ACDF. For those reasons, FSU height was chosen as an alternative method for evaluating the maintenance of disc height or directly determining whether the implant had subsided. FSU Success was

Table 1. Definition of Overall Success. All of the following were required for a patient's outcome to be considered an Overall Success (Reprinted with permission from Gornet MF, Burkus JK, Shaffrey ME, Argires PJ, Nian H, Harrell FE: Cervical disc arthroplasty with PRESTIGE LP disc versus anterior cervical discectomy and fusion: a prospective, multicenter investigational device exemption study. J Neurosurg Spine. 2015 Jul 31:1-16. [Epub ahead of print] PMID: 26230424.[22]).

Variables	Definition
Neck Disability Index (NDI) Success	≥15-point improvement postoperatively compared to preoperative score
Neurological Status Success	Maintenance or improvement in postoperative neurological status (motor function, sensory function, and reflexes) compared to preoperative condition
Functional Spinal Unit (Disc Height) Success	Functional spinal unit anterior or posterior measurement height declined by no more than 2 mm vs. the 6-week postoperative assessment
No serious adverse event classified as implant or implant/surgical procedure associated	Serious AE = Grade 3 or Grade 4 per World Health Organization criteria (typically, resulting in ER visit or hospitalization)
No secondary surgical procedure classified as a "failure"	Supplemental fixation, removal or revision = treatment failure. Reoperation or other surgical procedure ≠ treatment failure

AE = adverse event, ER = emergency room.

concluded when neither the anterior nor posterior measurement had declined by more than 2 mm compared with the 1.5-month postoperative assessment.

Segmental motion at the index and superior/inferior adjacent levels was measured on lateral dynamic flexion-extension radiographs using the Cobb method. Radiographic Success required angular motion at the level of surgery to be >4° but <20° at each postoperative interval.

Device Safety/Adverse Events

In addition to Neurological Success—maintenance or improvement in motor function, sensory function, and reflexes—the nature and frequency of adverse events were compared between study groups. An AE mapping scheme for terms and categories of AEs was proposed by the FDA, based in part on the study sponsor's internal AE process and in part on the MedDRA (Medical Dictionary for Regulatory Activities) coding system. This hybrid places each of 20 classifications of AEs under a broad body system (e.g., neurological, cardiac disorders), incident (e.g., trauma, infection), or other (associated conditions/systems with small numerical incidence). Adverse events were analyzed and characterized by their nature into categories, and graded according to World Health Organization criteria as "nonserious" (Grade 1 or 2) or "serious" (Grade 3 or 4) events. Reported AEs were likewise classified based on their potential relation to the implant and/or the surgical procedure. The AE data submitted to FDA, and used for this publication, were generated by a committee of three independent physicians which adjudicated all AE relationships and their severity. An adverse event that resulted in a second surgical procedure would cause the patient to be classified as a study "failure" with respect to the Overall Success determination if it required a supplemental fixation, implant removal, or a revision.

Patient Demographics

Patients in the nonrandomized investigational group and the historical control group were similar demographically (Table 2). Propensity scores were calculated using logistic regression modeling and included in the outcome models to adjust for possible effects of demographic characteristics or preoperative measures on clinical outcomes. Covariate balance after propensity score adjustment was examined using ANCOVA or logistic regression.

Table 2. Patient demographic and preoperative characteristics: median, interquartile range, (mean ± standard deviation) or percent (count) (Reprinted with permission from Gornet MF, Burkus JK, Shaffrey ME, Argires PJ, Nian H, Harrell FE: Cervical disc arthroplasty with PRESTIGE LP disc versus anterior cervical discectomy and fusion: a prospective, multicenter investigational device exemption study. J Neurosurg Spine. 2015 Jul 31:1-16. [Epub ahead of print] PMID: 26230424.[22]).

	Investigational (N=280)		Control (N=265)		p Value before PS Adjustment*	P value after PS Adjustment	
						PS as Continuous Covariate†	PS Stratification‡
Age (yrs)	39 44 49	(44.5±8.8)	38 44 49	(43.9±8.8)	0.369	0.997	0.873
Height (in)	64 67 71	(67.7±4.1)	64 67 71	(67.5±4.2)	0.622	0.998	0.946
Weight (lbs)	154 180 218	(186.9±45.0)	155 181 210	(184.7±41.5)	0.565	0.998	0.962
NDI score	44 54 66	(55.5±14.7)	44 58 68	(56.4±15.9)	0.499	0.997	0.952
SF36 PCS score	27.4 32.4 36.7	(32.2±7.4)	27.1 31.5 36.6	(32.0±7.5)	0.775	0.999	0.898
SF36 MCS score	34.9 46.5 53.6	(44.5±11.5)	33.1 42.1 53.0	(42.7±12.4)	0.078	0.993	0.924
Neck pain score	50 70 81	(60.7±20.8)	56 72 81	(69.3±21.5)	0.190	0.995	0.987
Arm pain score	40 64 80	(59.6±26.3)	42 67 83	(62.4±28.5)	0.237	0.995	0.960
Female	53.9%	(151)	54.0%	(143)	1.000	1.000	0.881
Race					0.075	0.997	0.708
Caucasian	96.8%	(271)	91.7%	(243)			
Black	2.5%	(7)	4.9%	(13)			
Asian	0.0%	(0)	0.8%	(2)			
Hispanic	0.4%	(1)	2.3%	(6)			
Other	0.4%	(1)	0.4%	(1)			
Marital status					0.109	0.990	0.749
Single	14.3%	(40)	12.1%	(32)			
Married	67.5%	(189)	77.0%	(204)			
Divorced	15.0%	(42)	9.1%	(24)			
Separated	2.5%	(7)	1.1%	(3)			
Widowed	0.7%	(2)	0.8%	(2)			
Education level					0.063	0.991	0.877
<High school	5.4%	(15)	5.3%	(14)			
High school	20.5%	(57)	29.2%	(77)			
>High school	74.1%	(206)	65.5%	(173)			
Workers' compensation case	11.4%	(32)	13.2%	(35)	0.616	0.998	0.864
Unresolved spinal litigation case	12.1%	(34)	12.1%	(32)	1.000	1.000	0.928
Tobacco used	26.4%	(74)	34.7%	(92)	0.045	0.991	0.893
Alcohol used	53.6%	(150)	53.2%	(141)	1.000	1.000	0.900
Working before operation	67.1%	(188)	62.6%	(166)	0.312	0.996	0.968
Non-narcotic relaxant medication use	74.3%	(208)	71.1%	(187)	0.462	0.997	0.836
Weak narcotic medication use	47.7%	(133)	48.3%	(127)	0.954	1.000	0.843
Strong narcotic medication use	22.2%	(62)	22.0%	(58)	1.000	1.000	0.995
Muscle relaxant medication use	35.8%	(100)	43.2%	(114)	0.097	0.993	0.977
Time to start having symptoms					0.488	0.999	0.992
<6 weeks	7.9%	(22)	5.7%	(15)			
6 weeks to 6 months	30.4%	(85)	33.6%	(89)			
>6 months	61.8%	(173)	60.8%	(161)			
Normal motor functions	38.2%	(107)	59.6%	(158)	<0.001	0.979	0.751

Normal sensory functions	41.8%	(117)	50.9%	(135)	0.040	0.991	0.890
Normal reflexes	66.4%	(186)	61.1%	(162)	0.231	0.995	0.888
Normal gait score	93.6%	(262)	77.0%	(204)	<0.001	0.881	0.467
Positive foraminal compression test	42.9%	(120)	54.3%	(144)	0.009	0.989	0.875
Treatment level					0.201	0.989	0.981
C3-C4	1.4%	(4)	3.8%	(10)			
C4-C5	7.5%	(21)	5.7%	(15)			
C5-C6	52.5%	(147)	56.2%	(149)			
C6-C7	38.6%	(108)	34.3%	(91)			

NDI = Neck Disability Index, MCS = Mental Component Score, PCS = Physical Component Score, **PS** = propensity score. *P values are from ANOVA for continuous variables and from Chi-square test for categorical variables. †For continuous variables, p-values are from ANCOVA and for categorical variables, from logistic regression; propensity score as a continuous covariate for both. ‡For continuous variables, p-values are from ANCOVA and for categorical variables, from the CMH test. †, ‡For categorical variables with multiple categories, they were dichotomized (except for treatment level) in the logistic regression models for calculating propensity scores to increase model stability and to check the covariate balance between treatment groups.

Eligible patients, who consented and were enrolled at sites with institutional review board approval, were all considered candidates for single-level ACDF because of symptomatic cervical DDD at a single level from C3-4 to C6-7, including neck and arm pain that was recalcitrant to nonoperative measures. These nonoperative treatment modalities may have included reduction of painful activities, physical therapy, anti-inflammatory medications, and other directed programs, for at least 6 weeks before surgery (Table 3).

Results

Patient Accountability

In the investigational CDA group, 280 patients were enrolled and treated at 20 separate sites. The historical control group consisted of 265 patients treated with ACDF. Follow-up rates at 84 months were 75.9% for the investigational group and 70.0% for the control group, based on the availability of Overall Success (without FSU) outcomes. Follow-up rates based on the availability of any data on a patient at a given study period were 82.0% for CDA patients and 76.2% for ACDF patients.

Patient Demographics

Despite the use of an historical control, the investigational and control groups were similar demographically because inclusion and exclusion criteria were the same for both FDA studies. Statistical differences in tobacco use (higher in the control group) and in race were appropriately balanced for statistical comparison after the application of propensity score adjustment techniques. There were no statistical differences between groups with respect to preoperative medical history or condition, medical usage, or preoperative scores of key efficacy endpoints. Overall,

Table 3. Study patient inclusion and exclusion criteria. Reprinted with permission from Gornet MF, Burkus JK, Shaffrey ME, Argires PJ, Nian H, Harrell FE: Cervical disc arthroplasty with PRESTIGE LP disc versus anterior cervical discectomy and fusion: a prospective, multicenter investigational device exemption study. J Neurosurg Spine. 2015 Jul 31:1-16. [Epub ahead of print] PMID: 26230424.[22]

INCLUSION (ALL)	EXCLUSION (ANY)
• **Cervical degenerative disc disease defined as intractable radiculopathy and/or myelopathy with at least one of the following items producing symptomatic nerve root and/or spinal cord compression that is documented by patient history [(*e.g.*, pain, functional deficit, and/or neurological deficit radiographic studies (*e.g.*, CT, MRI, x-rays, etc.)]:** • **herniated disc** • **osteophyte formation** • **One level requiring surgical treatment** • **C3-C4 disc to C6-C7 disc level of involvement** • **Unresponsive to nonoperative treatment for approximately six weeks or has the presence of progressive symptoms or signs of nerve root/spinal cord compression in the face of continued nonoperative management** • **No previous surgical intervention at the involved level or any subsequent, planned/staged surgical procedure at the involved or adjacent level(s)** • **Is at least 18 years of age, inclusive, at the time of surgery** • **Preoperative Neck Disability Index score ≥30** • **Has a preoperative neck pain score of ≥20 based on the Preoperative Neck and Arm Pain Questionnaire** • **If a female of child-bearing potential, patient is not pregnant, at the time of surgery** • **Is willing to comply with the study plan and sign the Patient Informed Consent Form**	• Has a cervical spinal condition other than symptomatic cervical disc disease requiring surgical treatment at the involved level; • Documented or diagnosed cervical instability defined by dynamic (flexion/extension) radiographs showing: • Sagittal plane translation > 3.5 mm or • Sagittal plane angulation > 20° • More than one cervical level requiring surgical treatment • Has a fused level adjacent to the level to be treated • Has severe pathology of the facet joints of the involved vertebral bodies • Previous surgical intervention at the involved level • Has been previously diagnosed with osteopenia or osteomalacia • Has any of the following that may be associated with a diagnosis of osteoporosis (if "Yes" to any of the below risk factors, a bone density scan will be required to determine eligibility): ◦ Postmenopausal non-Black female over 60 years of age and weighs less than 140 pounds ◦ Postmenopausal female that has sustained a non-traumatic hip, spine, or wrist fracture. • Male over the age of 70 • Male over the age of 60 that has sustained a non-traumatic hip or spine fracture • If the level of BMD is a T score of –3.5 or lower (*i.e.*, -3.6, -3.7, etc.) or a T score of –2.5 or lower (*i.e.*, -2.6, -2.7, etc.) with vertebral crush fracture, then the patient is excluded from the study • Has presence of spinal metastases • Has overt or active bacterial infection, either local or systemic • Has severe insulin dependent diabetes • Has chronic or acute renal failure or prior history of renal disease • Has fever (temperature > 101°F oral) at the time of surgery • Has a documented allergy to stainless steel, titanium, or a titanium alloy • Is mentally incompetent (If questionable, obtain psychiatric consult) • Is a prisoner • Is pregnant • Is an alcohol and/or drug abuser as defined by currently undergoing treatment for alcohol and/or drug abuse • Has received drugs which may interfere with bone metabolism within two weeks prior to the planned date of spinal surgery (*e.g.*, steroids or methotrexate), excluding routine perioperative anti-inflammatory drugs • Has a history of endocrine or metabolic disorder known to affect osteogenesis (*e.g.*, Paget's Disease, renal osteodystrophy, Ehlers-Danlos Syndrome, or osteogenesis imperfecta) • Has a condition that requires postoperative medications that interfere with the stability of the implant, such as steroids. (This does not include low dose aspirin for prophylactic anticoagulation), excluding routine perioperative anti-inflammatory drugs • Has received treatment with an investigational therapy within 28 days prior to implantation surgery or such treatment is planned during the 16 weeks following Artificial Cervical Disc-LP implantation

CT = computed tomography, MRI = magnetic resonance imaging

DOI: 10.14444/3024

the 2 study groups were similar prior to surgery (Table 2), with potential confounding effects statistically adjusted, such that conclusions reached by the statisticians were based on treatment effect rather than any potential confounding influences.

Surgical Data

More than 90% of patients in each group were treated at the C5-C6 or C6-C7 level using a standard extrapharyngeal anterolateral approach. Mean operative time in the investigational and control groups was 1.49 hours and 1.38 hours, respectively, a statistically significant difference of approximately 6.5 minutes (95% credible interval, 0.01 to 0.21 hours). Blood loss (51.0 mL - investigational and 57.1 mL - control) and hospital stay (0.98 day - investigational and 0.95 day - control) were not statistically different between the groups.

Overall Success

At 84 months, the rate of Overall Success (without FSU height success) in the investigational group exceeded the rate in the control group by 0.109 (95% credible interval 0.011 to 0.208), and with FSU by 0.001(95% credible interval -0.122 to 0.125), respectively (Table 4). The posterior probability that the Overall Success rate (without FSU) in the investigational group was higher than the control group was 0.985, indicating statistical superiority.

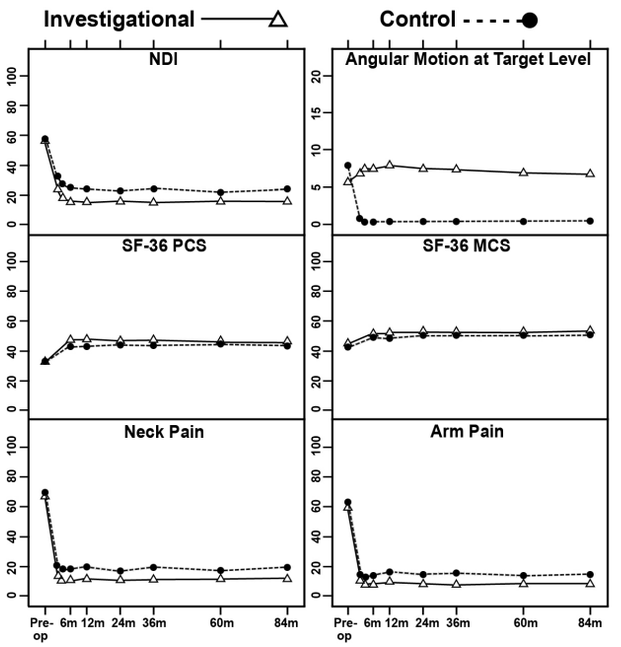

Fig. 2. Mean Neck Disability Index (NDI), angular motion at target level, Short-Form-36 Physical Component Summary (SF-36 PCS), Short-Form-36 Mental Component Summary (SF-36 MCS), and neck pain and arm pain scores of the 2 treatment groups at baseline and postoperative time points. Vertical bars indicate 99% confidence intervals of the means.

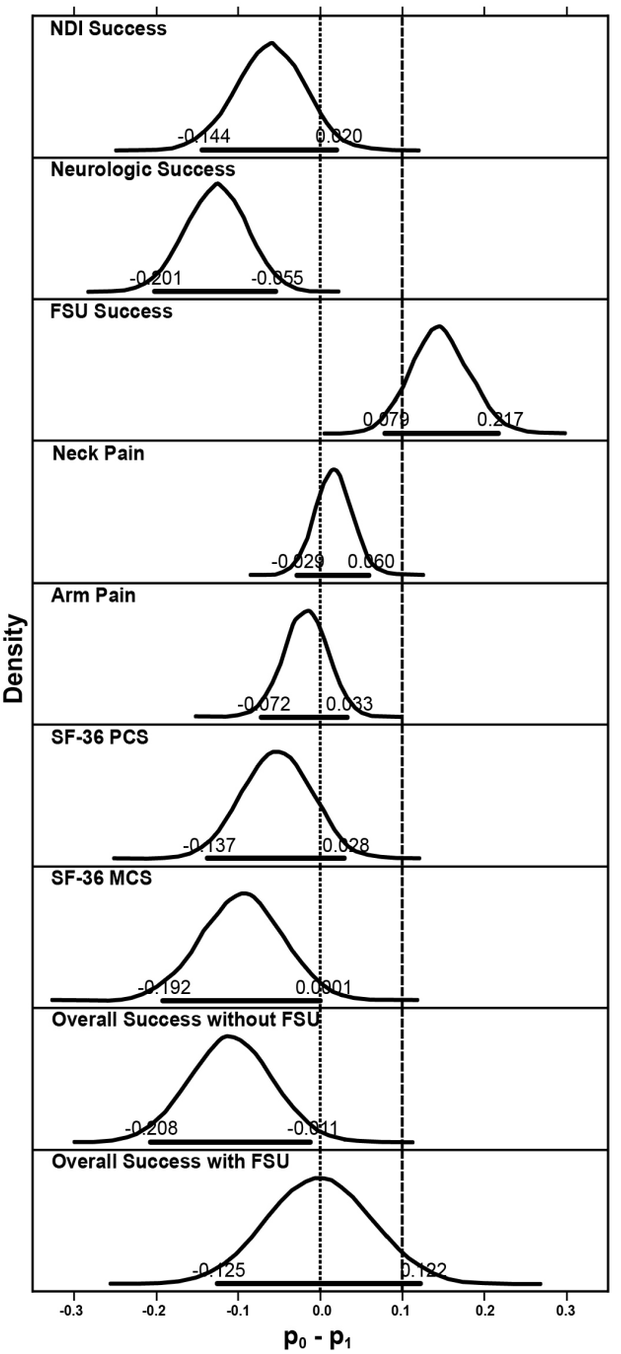

Fig. 3. Posterior distributions of differences in success rates of efficacy and neurological variables between the 2 treatment groups. Horizontal bold lines indicate 95% HPD, upper and lower limits of which are also labeled. Dashed vertical line is upper limit of noninferiority and dotted vertical line is upper limit of superiority. FSU = functional spinal unit, HPD = highest posterior density, NDI = Neck Disability Index, SF-36 MCS = Short-Form-36 Mental Component Summary, SF-36 PCS = Short-Form-36 Physical Component Summary.

Table 4. Comparisons of efficacy and neurological variables at 84 months.

Measure			**p_1 (Investigational)**		**p_0 (Control)**		**$p_0 - p_1$**		**Probability of Superiority**	
	% Investigational	% Control	Mean	95% HPD	Mean	95% HPD	Mean	95% HPD	Non-inferiority	Superiority
NDI	86.06% (179/208)	80.11% (145/181)	0.862	(0.810, 0.908)	0.801	(0.735, 0.859)	-0.061	(-0.144, 0.020)	~1.000	0.932
Neurological status	92.75% (192/207)	79.67% (145/182)	0.927	(0.887, 0.959)	0.800	(0.737, 0.858)	-0.127	(-0.201, -0.055)	~1.000	~1.000
FSU	83.65% (133/159)	96.85% (123/127)	0.827	(0.761, 0.885)	0.973	(0.940, 0.993)	0.146	(0.079, 0.217)	0.093	0.000
Neck pain	94.69% (196/207)	95.56% (172/180)	0.945	(0.908, 0.972)	0.961	(0.928, 0.984)	0.016	(-0.029, 0.060)	~1.000	0.234
Arm pain	94.20% (195/207)	92.78% (167/180)	0.945	(0.908, 0.972)	0.927	(0.884, 0.961)	-0.018	(-0.072, 0.033)	~1.000	0.748
SF-36 PCS	85.29% (174/204)	79.21% (141/178)	0.851	(0.797, 0.898)	0.797	(0.732, 0.856)	-0.053	(-0.137, 0.028)	~1.000	0.894
SF-36 MCS	77.45% (158/204)	70.22% (125/178)	0.786	(0.724, 0.840)	0.690	(0.616, 0.758)	-0.095	(-0.192, 0.0001)	~1.000	0.975
Overall success (w/o FSU)	74.88% (158/211)	63.19% (115/182)	0.746	(0.683, 0.804)	0.637	(0.563, 0.709)	-0.109	(-0.208, -0.011)	~1.000	0.985
Overall success (w/ FSU)	62.05% (103/166)	60.00% (81/135)	0.612	(0.533, 0.688)	0.611	(0.520, 0.696)	-0.001	(-0.125, 0.122)	0.947	0.508

FSU = functional spinal unit, HPD = highest posterior density, MCS = Short Form-36 Mental Component Summary, NDI = Neck Disability Index, SF-36 PCS = Short Form-36 Physical Component Summary.

Efficacy Endpoints

For both the investigational and control groups, improvements in pain and disability scores compared with preoperative assessments were highly significant ($p < 0.001$, paired *t*-tests) for NDI, SF-36 PCS and MCS, numeric neck pain and arm pain scores, from 1.5 months after surgery up to 84 months (Figure 2). Mean NDI improvement in both groups exceeded 30 points from 6 months after surgery through 84 months.

Bayesian methods were used to evaluate the secondary endpoints. Compared with the control fusion group, the investigational group achieved higher numerical rates of NDI success, neurological success, arm pain success, SF-36 PCS success and MCS success at 84 months; success rates were numerically lower than the control group for FSU height and neck pain (Table 4). The posterior probabilities that the success rate in the control group was less than 10% higher than in the investigational group were essentially 1.0 for all outcomes except FSU height, thus demonstrating statistical noninferiority of the investigational group to the control group for these outcomes 7 years after surgery (Figure 3). The posterior probabilities that the success rate in the investigational group was higher than control group were essentially 1.000, 0.975, and 0.985 for neurological status, SF-36 MCS, and Overall Success without FSU. These Bayesian probabilities exceeded the threshold of 0.95, providing for a conclusion of statistical superiority of the investigational group over the control group for the 3 variables.

Treatment Effectiveness/Patient Satisfaction

At each postoperative interval, patients were asked to evaluate the effectiveness of their treatment based on their pain, and in both groups, the percentage of patients choosing "completely recovered" or "much improved" remained consistently high out to 84 months after surgery: 86.1% of investigational and 77.4% of control patients. Seven years after their treatment, approximately 91% of CDA patients and 86% of ACDF patients were satisfied with the results of their surgery and would have the surgery again (Table 5).

Radiographic Assessment

Measurements of the FSU were made by the independent core lab over the course of the 7 years after each surgery in an effort to monitor disc height changes. A success or failure determination could not be made for approximately 40% of the investigational group at 84 months, due to both the gradual reduction in patient follow-up and to the visualization challenges inherent even in this measurement technique, which was a proxy for the more traditional endplate-to-endplate disc height measurement. In those patients for whom a measurement was obtained, FSU Success was above 90% for both treatment groups at all follow-up intervals, with the exception of the investigational group at 84 months with an 83.6% success rate; statistical noninferiority could not be concluded at 84 months.

The core lab also measured angular and translational motion at the index and adjacent levels at each postoperative follow-up visit. In the investigational group, mean angular motion was maintained through 84 months (6.78°), and mean translational motion was consistent throughout the postoperative course at the index level.

Adjacent level motion was also measured preoperatively and at each follow up. In the investigational group, mean angulation at the superior/inferior levels was 8.51°/6.09° preoperatively and 9.31°/6.17° at 84 months. In the control fusion group, superior/inferior adjacent level motion was 10.77°/7.77° preoperatively and 10.71°/8.46° at 84 months. Mean changes in adjacent level angular motion for each follow-up interval are presented in Table 6.

Heterotopic ossification was not included in the protocol-defined reporting responsibilities of the independent radiology reviewers. However, bridging bone, defined as evidence of a continuous connection of trabecular bone between vertebral bodies, was reported by the radiology core lab in 13.0% of investigational patients at 84 months. The relatively consistent mean angulation measurements at the index and adjacent levels, and the highly significant mean improvement in pain and disability scores up to 84 months after surgery, indicate little impact clinically from the bridging bone measures.

Adverse Events

A time course summary of operative and postoperative adverse events is presented in Table 7, reporting the total number of AEs in each category and the number of patients involved. Statistical comparisons of the AE occurrence rates were made using predefined Bayesian methods (Table 8). Up to 84 months, the investigational group had a statistically higher rate of overall AEs, with a higher rate for the categories of anatomical or technical difficulty, implant event, urogenital AE, and vascular AE. As expected, the rate of nonunion events was significantly higher in the control group. To account for patients lost to follow up over the 7-year period, we conducted time-to-event analyses (Figure 4). The conclusion remains similar, except that the category of anatomical or technical difficulty is no longer statistically different between the 2 groups.

Table 5. Patient satisfaction at 84 months.

Questionnaire	Investigational % (n)		Control % (n)	
I am satisfied with the results of my surgery				
Definitely true	79.3%	(165)	60.8%	(110)
Mostly true	11.5%	(24)	24.9%	(45)
Do not know	6.3%	(13)	6.1%	(11)
Mostly false	1.0%	(2)	5.0%	(9)
Definitely false	1.9%	(4)	3.3%	(6)
I was helped as much as I thought I would be				
Definitely true	74.5%	(155)	59.9%	(106)
Mostly true	14.9%	(31)	23.7%	(42)
Do not know	4.8%	(10)	6.8%	(12)
Mostly false	3.8%	(8)	4.0%	(7)
Definitely false	1.9%	(4)	5.6%	(10)
All things considered I would have the surgery again				
Definitely true	80.1%	(172)	72.3%	(128)
Mostly true	7.7%	(16)	12.4%	(22)
Do not know	5.8%	(12)	10.7%	(19)
Mostly false	1.4%	(3)	2.3%	(4)
Definitely false	1.9%	(4)	2.3%	(4)

Table 6. Postoperative mean angular motion at adjacent levels.

	Investigational (N=280)			Control (N=265)		
	N	Mean±SD	P value	N	Mean±SD	P value
1.5 months						
Change in angulation at the segment above (°)	266	-0.77±3.61	<0.001	187	-1.13±4.39	<0.001
Change in angulation at the segment below (°)	172	-0.25±3.17	0.298	86	0.70±3.67	0.081
3 months						
Change in angulation at the segment above (°)	264	0.32±3.85	0.175	194	0.06±4.27	0.841
Change in angulation at the segment below (°)	174	0.29±3.48	0.266	91	1.21±3.71	0.002
6 months						
Change in angulation at the segment above (°)	263	0.82±3.84	<0.001	198	0.53±4.26	0.084
Change in angulation at the segment below (°)	166	0.65±3.69	0.025	94	0.99±3.93	0.017
12 months						
Change in angulation at the segment above (°)	267	1.27±3.75	<0.001	188	1.32±4.41	<0.001
Change in angulation at the segment below (°)	166	1.11±3.47	<0.001	95	1.89±4.50	<0.001
24 months						
Change in angulation at the segment above (°)	262	1.88±3.84	<0.001	187	1.04±4.60	0.002
Change in angulation at the segment below (°)	161	1.13±3.75	<0.001	94	1.28±4.28	0.005
36 months						
Change in angulation at the segment above (°)	225	1.53±3.92	<0.001	139	0.20±5.30	0.639
Change in angulation at the segment below (°)	143	1.69±3.83	<0.001	67	0.74±4.52	0.187
60 months						
Change in angulation at the segment above (°)	188	1.37±3.99	<0.001	159	-0.17±4.79	0.663
Change in angulation at the segment below (°)	117	1.11±4.37	0.007	75	0.85±4.95	0.143
84 months						
Change in angulation at the segment above (°)	194	1.06±4.39	<0.001	152	-0.23±5.37	0.604
Change in angulation at the segment below (°)	127	1.25±4.06	<0.001	70	1.25±5.07	0.043

Table 7. Time course summary of adverse events

Interval*	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**6**	**6**	**7**	**7**	**8**	**8**	**9**	**9**	**10**	**10**	**11**	**11**	**12**	**12**	**Total**	**Total**
	E†	P‡	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P (%)
Investigational(N=280)																										
Any adverse event	29	25	173	80	179	89	241	117	246	115	401	146	312	116	328	97	218	79	300	89	222	71	125	62	2774	271 (96.8)
Anatomical/technical difficulty	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	3	3 (1.1)
Cancer	0	0	1	1	0	0	0	0	1	1	3	2	0	0	4	2	0	0	2	2	0	0	1	1	12	6 (2.1)
Cardiac disorders	0	0	2	1	2	1	0	0	2	2	5	4	11	8	6	4	8	7	11	6	8	7	6	6	61	39 (13.9)
Death	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	2	2 (0.7)
Dysphagia/dysphonia	1	1	15	12	4	4	5	5	4	3	0	0	2	2	5	5	1	1	0	0	0	0	0	0	37	31 (11.1)
Gastrointestinal	2	1	8	6	1	1	3	3	3	3	20	13	18	9	19	9	19	11	23	14	20	13	4	3	140	64 (22.9)
Heterotopic ossification	0	0	2	2	6	5	2	2	4	3	3	3	6	6	5	5	5	5	6	6	5	4	8	7	52	44 (15.7)
Implant events	6	6	1	1	2	2	2	2	0	0	0	0	4	4	1	1	1	1	4	4	0	0	1	1	22	20 (7.1)
Infection	1	1	5	4	5	5	6	5	10	9	14	11	11	10	18	16	6	5	23	12	9	8	9	7	117	61 (21.8)
Neck and/or arm pain	3	2	35	23	54	41	70	49	52	37	76	54	49	29	39	26	25	20	37	25	29	19	14	10	483	186 (66.4)
Neurological	2	2	14	11	23	16	36	30	24	20	69	48	31	20	25	18	15	12	20	13	23	13	8	7	290	147 (52.5)
Non-union	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	3	2 (0.7)
Other	4	4	19	15	14	12	23	14	29	22	56	40	29	22	40	22	38	25	45	32	45	27	25	17	367	142 (50.7)
Other pain	4	4	19	19	33	28	48	38	53	40	69	48	48	32	64	46	50	33	52	36	25	19	21	17	486	181 (64.6)
Respiratory	0	0	8	6	0	0	1	1	11	8	1	1	13	11	3	3	1	1	13	10	12	7	5	4	68	46 (16.4)
Spinal event	0	0	22	13	25	14	26	16	26	20	52	30	44	18	68	27	16	10	25	15	24	10	13	9	341	127 (45.4)
Trauma	0	0	6	6	5	5	13	12	12	12	20	19	20	18	18	17	14	11	15	13	11	9	9	9	143	106 (37.9)
Urogenital	1	1	1	1	2	2	1	1	8	6	11	8	16	12	7	6	14	8	14	11	7	6	1	1	83	51 (18.2)
Vascular	3	3	1	1	1	1	1	1	2	2	0	0	5	4	4	3	4	4	5	3	4	3	0	0	30	24 (8.6)
Wound (non-infectious)	0	0	14	10	2	2	4	3	4	1	2	2	5	4	2	2	0	0	1	1	0	0	0	0	34	23 (8.2)
Control (N=265)																										

Any adverse event	34	19	119	66	97	47	211	94	143	79	280	104	341	117	235	82	256	82	251	88	153	53	116	51	2236	232 (87.5)
Anatomical/technical difficulty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 (0.0)
Cancer	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0	5	5 (1.9)
Cardiac disorders	0	0	2	2	1	1	2	2	3	2	3	3	9	9	7	4	5	4	5	5	6	6	3	3	46	37 (14.0)
Death	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	2	2	0	0	0	0	0	0	5	5 (1.9)
Dysphagia/dysphonia	5	4	11	11	4	4	3	3	0	0	1	1	0	0	0	0	3	2	4	4	0	0	0	0	31	26 (9.8)
Gastrointestinal	7	4	7	5	3	2	4	4	3	3	21	12	24	13	8	7	16	11	12	8	9	5	6	5	120	64 (24.2)
Heterotopic ossification	0	0	1	1	4	1	2	2	1	1	3	3	11	9	3	3	8	8	5	4	3	3	3	3	44	34 (12.8)
Implant events	0	0	1	1	1	1	0	0	0	0	2	2	1	1	1	1	0	0	4	3	1	1	0	0	11	9 (3.4)
Infection	2	1	3	3	5	5	2	2	1	1	10	9	14	10	10	9	6	6	4	4	10	9	11	8	78	49 (18.5)
Neck and/or arm pain	2	1	18	14	19	15	49	37	42	33	55	44	41	28	28	19	36	24	23	19	5	3	24	18	342	156 (58.9)
Neurological	6	5	24	20	18	11	36	24	17	13	57	34	61	35	42	29	28	19	30	24	11	11	18	12	348	144 (54.3)
Non-union	0	0	0	0	3	3	4	4	9	9	9	9	9	9	1	1	0	0	2	2	0	0	1	1	38	35 (13.2)
Other	3	2	14	12	13	10	17	13	10	10	20	14	54	31	26	19	31	24	43	27	31	19	13	12	275	123 (46.4)
Other pain	6	4	19	16	10	10	44	33	28	25	58	40	60	43	49	34	45	33	50	33	30	24	19	15	418	167 (63.0)
Respiratory	0	0	4	3	4	2	1	1	5	4	1	1	8	7	4	4	2	2	10	8	8	5	3	2	50	32 (12.1)
Spinal event	0	0	8	6	6	5	30	15	15	9	22	12	33	17	31	16	47	25	30	18	14	8	6	5	242	106 (40.0)
Trauma	0	0	2	2	4	4	12	11	5	5	9	8	12	10	15	14	20	20	15	14	15	13	7	7	116	79 (29.8)
Urogenital	0	0	0	0	0	0	1	1	3	3	5	4	2	2	6	4	5	3	11	7	7	5	1	1	41	26 (9.8)
Vascular	1	1	0	0	0	0	1	1	0	0	1	1	0	0	1	1	2	2	1	1	1	1	0	0	8	8 (3.0)
Wound (non-infectious)	2	2	4	4	2	2	2	2	1	1	2	2	0	0	2	2	0	0	1	1	1	1	1	1	18	18 (6.8)

*Intervals: (1) Operative; (2) 1 day; (3) 1.5 months; (4) 3 months; (5) 6 months;(6) 12 months; (7) 24 months; (8) 36 months; (9) 48 months; (10) 60 months; (11) 72 months; (12) 84 months. †E = Number of events; ‡P = Number of patients.

Any adverse event that required a second surgery at the index level was classified according to the protocol in 1 of 4 ways: revisions, removals, supplemental fixations, or reoperations. A revision was defined as a procedure that adjusted or in any way modified the original implant configuration. A removal was defined as a procedure that removed 1 or more components of the original implant configuration without replacement with the same type of device. Supplemental fixation was defined as a procedure in which additional spinal devices not approved as part of the protocol were placed and included supplemental treatments, such as bone growth stimulators. A reoperation was defined as any surgical procedure at the treated spinal level that did not remove, modify, or add any components. Secondary surgical interventions occurred in both treatment groups, and results at 84 months are compared in Table 9. The mean difference in the rate of supplemental fixation procedures between the investigational and the control group was -0.030 (95% credible interval was -0.058 to -0.009). The posterior probability that the investigational group had a lower rate of supplemental fixation procedures was 0.998, demonstrating statistical superiority of the investigational group over the control group. Excluding external bone growth stimulators from supplemental fixation, rates were similar between the 2 groups. To account for patients lost to follow-up, time-to-event analyses were also conducted, with no resulting change in conclusions (Figure

Table 8. Comparisons of adverse events at 84-month interval.

Variable	p_1 (Investigational)		p_0 (Control)		$p_1 - p_0$		Probability of Superiority
	Mean	95% HPD	Mean	95% HPD	Mean	95% HPD	
Anatomical/technical difficulty	0.006	(0.0003, 0.019)	0.000	(0.000, 0.000)	0.006	(0.0003, 0.019)	0.003
Cancer	0.023	(0.008, 0.044)	0.014	(0.004, 0.032)	0.009	(-0.015, 0.033)	0.224
Cardiac disorders	0.127	(0.090, 0.170)	0.148	(0.106, 0.196)	-0.021	(-0.084, 0.041)	0.749
Dysphagia/dysphonia	0.109	(0.075, 0.150)	0.098	(0.064, 0.139)	0.011	(-0.046, 0.066)	0.351
Gastrointestinal	0.228	(0.179, 0.281)	0.241	(0.189, 0.298)	-0.013	(-0.092, 0.064)	0.632
Heterotopic ossification	0.163	(0.121, 0.210)	0.122	(0.084, 0.166)	0.041	(-0.022, 0.105)	0.104
Implant events	0.074	(0.045, 0.110)	0.031	(0.014, 0.055)	0.044	(0.005, 0.085)	0.014
Infection	0.219	(0.171, 0.272)	0.183	(0.137, 0.234)	0.037	(-0.037, 0.109)	0.163
Neck and/or arm pain	0.658	(0.598, 0.715)	0.597	(0.536, 0.657)	0.061	(-0.027, 0.148)	0.086
Neurological	0.527	(0.466, 0.587)	0.542	(0.478, 0.605)	-0.015	(-0.108, 0.077)	0.624
Non-union	0.007	(0.001, 0.020)	0.133	(0.092, 0.181)	-0.126	(-0.174, -0.083)	~1.000
Other	0.498	(0.436, 0.560)	0.474	(0.412, 0.537)	0.025	(-0.067, 0.117)	0.300
Other pain	0.636	(0.575, 0.693)	0.643	(0.581, 0.702)	-0.007	(-0.096, 0.083)	0.552
Respiratory	0.155	(0.113, 0.202)	0.125	(0.088, 0.169)	0.030	(-0.034, 0.093)	0.176
Spinal event	0.463	(0.404, 0.525)	0.389	(0.327, 0.451)	0.074	(-0.015, 0.167)	0.053
Trauma	0.370	(0.313, 0.430)	0.305	(0.249, 0.364)	0.065	(-0.020, 0.151)	0.067
Urogenital	0.173	(0.129, 0.223)	0.102	(0.067, 0.143)	0.071	(0.007, 0.134)	0.016
Vascular	0.084	(0.053, 0.121)	0.030	(0.013, 0.056)	0.054	(0.014, 0.096)	0.005
Wound (non-infection)	0.089	(0.057, 0.127)	0.056	(0.032, 0.088)	0.032	(-0.013, 0.079)	0.086
Any adverse event	0.968	(0.943, 0.985)	0.877	(0.832, 0.917)	0.090	(0.044, 0.141)	0.000

HPD = highest posterior density.

DOI: 10.14444/3024

5).

The percentage of patients undergoing secondary surgeries at the adjacent level alone or in conjunction with the index level, cumulatively up to the 84-month follow up, was similar: 9.6% of investigational and 8.3% of control patients.

Device- and device/surgical procedure-related AEs were reported in 17.5% of investigational and 16.6% of control patients. The incidence of AEs that were both serious and classified as device- and device/surgical procedure-related events was also similar in the investigational (6.1%) and control (5.6%) groups.

Discussion

In this study, we report a continuation of the successful results seen at 24 months for patients treated with the Prestige LP Cervical Disc device at 7 years after

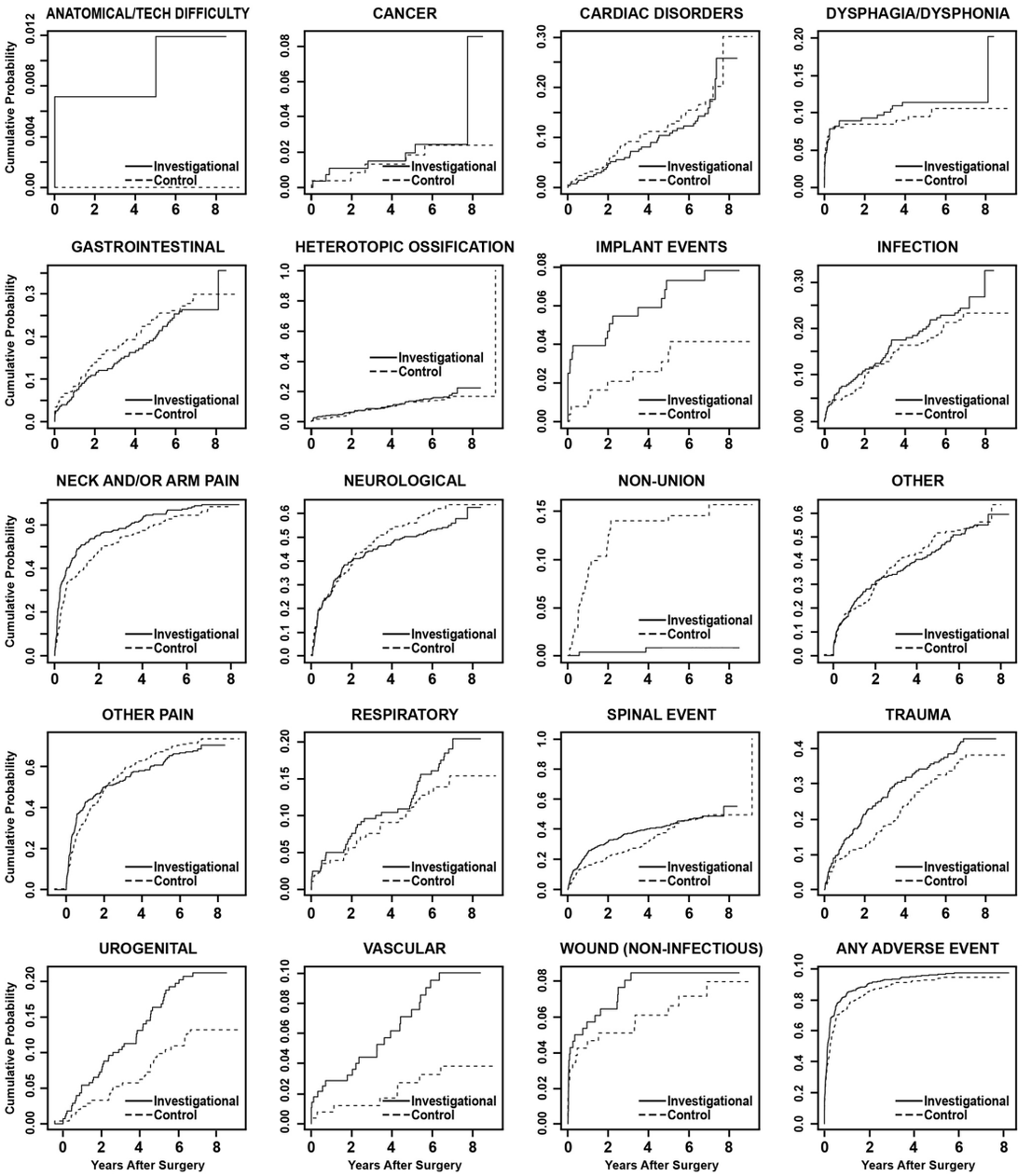

Fig. 4. Time-to-event analyses (Kaplan-Meier curves) showing cumulative probabilities by adverse event category for the investigational and control groups. P values are based on Cox proportional hazards models, adjusted for propensity score.

surgery. Statistical superiority or noninferiority was concluded for CDA compared with ACDF with respect to key clinical and radiographic outcomes, as improvements versus baseline in mean pain and disability measures were statistically significant in both groups at each follow-up interval after surgery. Safety measures including device- and device/surgical procedure-related adverse events and second surgeries were also statistically similar in the investigational and control groups out to seven years. Patient satisfaction was likewise high in both groups.

Articulating prosthetic implants are subject to wear and corrosion following implantation. An advantage of metal-on-metal bearings is the substantially lower volumetric wear debris when compared with conventional metal-on-polyethylene bearing couples. However, implant wear can lead to local and systemic

Table 9. Comparisons of secondary surgical events at 84 months.

Surgical Event	p_1 (Investigational)			p_0 (Control)			$p_1 - p_0$		Probability of Superiority
	N	Mean	95% HPD	N	Mean	95% HPD	Mean	95% HPD	
Revisions	1	0.004	(0.000, 0.014)	5	0.016	(0.004, 0.036)	-0.012	(-0.033, 0.003)	0.938
Removal	14	0.049	(0.026, 0.079)	8	0.030	(0.013, 0.054)	0.019	(-0.015, 0.055)	0.139
Supplemental Fixation	2	0.005	(0.0005, 0.015)	9	0.036	(0.016 0.063)	-0.030	(-0.058 -0.009)	0.998
Supplemental Fixation w/o BGS	2	0.005	(0.0005, 0.015)	5	0.019	(0.006, 0.040)	-0.014	(-0.035 0.002)	0.962
Reoperations	3	0.011	(0.002, 0.027)	4	0.011	(0.002, 0.027)	0.001	(-0.018, 0.018)	0.463
Other	130	0.460	(0.398, 0.522)	106	0.404	(0.344, 0.466)	0.056	(-0.037, 0.145)	0.119

BGS = bone growth stimulator, HPD = highest posterior density

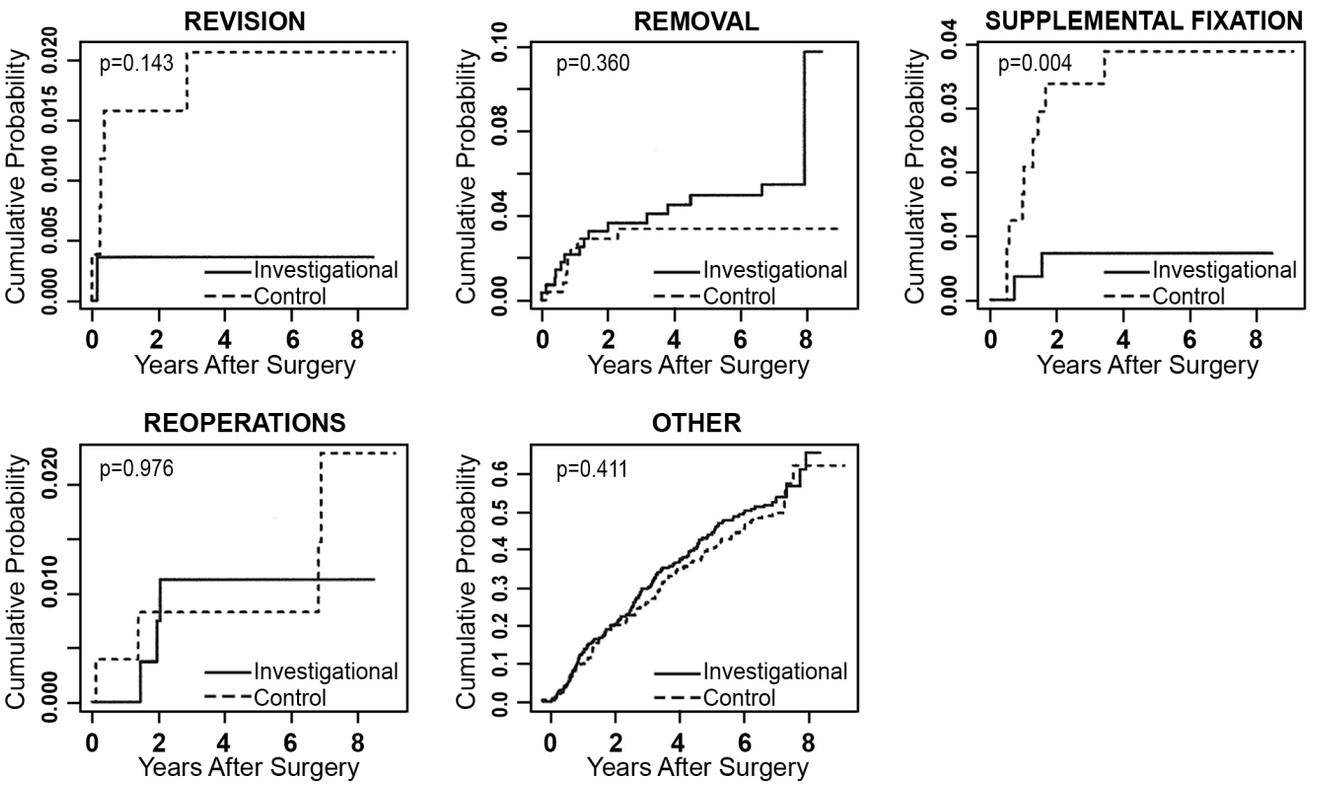

Fig. 5. Time-to-event analyses (Kaplan-Meier curves) showing cumulative probabilities of the classifications of secondary surgeries for the investigational and control groups. P values are based on Cox proportional hazards models, adjusted for propensity score.

transport of metal debris and increased levels of serum ions. Patients with Prestige LP cervical disc replacements experience increased serum metal ion concentrations after surgery (Gornet MF, Singh V, Schranck FW, Skipor AK, Jacobs JJ: Serum metal ion levels after surgery in patients with metal-on-metal cervical disc arthroplasty. A prospective study up to 84 months. Paper presented at the 30th Annual Meeting of the North American Spine Society. Chicago, IL, October 14-17, 2015). Importantly, the toxicological sequelae of these chronic elevated local and systemic metal levels have not been determined. Several case studies have reported some early local effect of wear debris.[25,26]

Cervical disc arthroplasty has the potential for preserving motion at the operated level while providing biomechanical stability and global neck mobility. Restoration or maintenance of physiologic motion at the treated level may result in a reduction in adjacent segment degeneration (ASD) and the need for additional surgery. Although cervical disc replacement and anterior cervical fusion are both safe procedures with a low incidence of significant adverse events related to the procedure, more additional surgeries occurred in the investigational group (CDA) than in the control (ACDF) group. Cervical disc arthroplasty may provide the benefits of neural decompression without placing adjacent motion segments at risk for accelerated degeneration; however, there is no consensus that CDA provides a reduction in ASD rates in longer-term studies.[13,19,27]

The absence of randomization in this study may be considered a shortcoming. This historical control approach, however, was approved by the FDA based on the identical inclusion/exclusion criteria, as well as the Bayesian propensity score techniques which provided statistical balance to all covariates and validated the comparability of the groups.

With one exception,[28] the rate of neurological success in the ACDF control group is lower than typically reported.[1,10,11,29] We cannot definitively explain this lower rate nor the rate difference between CDA and ACDF in the current study. Caution is advised in making comparisons across studies because measurement and reporting of neurological success varies, therefore, statistical comparisons may not be valid. We can, however, speculate about several possible reasons for the lower success rate in this study: surgical technique, pseudarthrosis rates, ASD, and bias. First, the surgical technique of the CDA involved a more thorough dissection and decompression than that required in the ACDF control group. The CDA required an extensive posterior and posterolateral decompression across the disc space. The entire posterior annulus and posterior longitudinal ligament were resected and uncovertebral joints were partially removed. This decompression may have been less meticulously performed in the ACDF group. Second, relatively high subsidence/pseudarthrosis rates after ACDF have been widely published and may contribute over time to unfavorable changes in neurological status. Third, the increasing incidence of ASD observed after ACDF may be contributing to new neurological pathology--especially as the length of follow-up increases. Finally, we cannot rule out the possible influence of expectations from the treating surgeons. In the absence of blinding, surgeons' expectations about inferior performance compared with new motion preservation technology may have negatively impacted their assessment of ACDF patients.

Several encouraging clinical and radiographic findings have come from the long-term patient follow-up of this prospective study with concurrent enrollment out to seven years after surgery using the Prestige LP implant. Statistically significant improvements in validated clinical outcome measurements were maintained out to 7 years.

The Prestige LP Disc maintained physiologic segmental motion at 84 months after implantation with a mean flexion-extension difference of 6.78°. Mean translational motion was consistent throughout the postoperative course at the index level. In addition, there were no reported implant migrations. The rates of spontaneous fusion, as measured by the presence of bridging bone, and subsidence, as measured by FSU height, were very low.

Thousands of patients have now undergone cervical disc arthroplasty in very large prospective, multicenter IDE studies in the United States, and this collec-

tive body of Level 1 evidence, much of it now with results up to 7 years after surgery, is consistent and convincing in its support of CDA as an alternative to ACDF in appropriately selected patients. In many of these published studies, the outcomes evidence includes a conclusion of statistical superiority for CDA compared with ACDF. Adding to that support is the growing body of longer term cost effectiveness data[18,30-32] that concludes that CDA is economically superior to ACDF. Nevertheless, single-level CDA utilization rates in the United States have thus far trailed expectations due, in part, to limited coverage and reimbursement by insurers.

Conclusions

Patients treated with the Prestige LP Cervical Disc reported significantly improved pain and disability outcomes, at least equivalent to those of the historical control fusion group, 84 months after surgery. Key measures of safety were similar for investigational and control patients. At 84 months, patient satisfaction with the results of surgery was high in both groups. Additional surgical procedures for adjacent segment disease were observed in both treatment groups. Some of the second surgeries involved both index and adjacent levels. Rates for surgery at adjacent levels were similar between the groups and were not statistically significant.

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Disclosures & COI

Dr. Burkus reports research support from Medtronic, during the conduct of the study; research support from Medtronic and Zimmer/Biomet outside the submitted work; In addition, Dr. Burkus has a patent with paid royalties from Zimmer/Biomet. Dr. Gornet reports stock ownership in Bonovo; stock in the International Spine and Orthopedic Institute; consultancy for K2M, research support, consultancy, and royalties from Medtronic; stock ownership in Nocimed; stock ownership in OuroBoros; stock ownership in Viscogliosi Brothers Venture Partners, outside the submitted work. Dr. Harrell has nothing to disclose. Dr. Nian reports contract funding for statistical analysis from Medtronic during the conduct of the study. Dr. Schaffrey has nothing to disclose.

This investigational device exemption study was sponsored by Medtronic Spinal and Biologics, Memphis, TN. Study approved by the Hughston Sports Medicine Center Institutional Review Board on January 7, 2005.

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Published 22 June 2016.