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Appendix 1 Studies Excluded After Full Text Review

More than 15% of Patients Had Fusion Extending to the Thoracic or Axial Spine

Deen HG, Birch BD, Wharen RE, Reimer R. Lateral mass screw-rod fixation of the cervical spine: a prospective clinical series with 1-year follow-up. Spine J. 2003 Nov-Dec;3(6):489-95.

Kelleher MO, McEvoy L, Yang JP, Kamel MH, Bolger C. Lateral mass screw fixation of complex spine cases: a prospective clinical study. Br J Neurosurg. 2008 Oct;22(5):663-8.

Kim SH, Shin DA, Yi S, Yoon H, Kim KN, Shin HC. Early results from posterior cervical fusion with a screw-rod system. Yonsei Med J. 2007 Jun 30;48(3):440-8.

Lee DC, Yoon SH, Park HC, Park JO, Hyun DK, Park HS. Clinical and computed tomography evaluation of plate and screw on the cervical lateral mass: a modified Magerl's technique. J Korean Neurosurg Soc. 2006 Apr;39(4):251-5.

Muffoletto AJ, Hadjipavlou AG, Jensen RE, Nauta HJ, Necessary JT, Norcross-Nechay K. Techniques and pitfalls of cervical lateral mass plate fixation. Am J Orthop (Belle Mead NJ). 2000 Nov;29(11):897-903.

Mummaneni PV, Haid RW, Traynelis VC, Sasso RC, Subach BR, Fiore AJ, Rodts GE. Posterior cervical fixation using a new polyaxial screw and rod system: technique and surgical results. Neurosurg Focus. 2002 Jan 15;12(1):E8. Epub 2002 Jan 15.

N < 10

Boulos AS, Lovely TJ. Degenerative cervical spondylolisthesis: diagnosis and management in five cases. J Spinal Disord. 1996 Jun;9(3):241-5.

Horgan MA, Kellogg JX, Chesnut RM. Posterior cervical arthrodesis and stabilization: an early report using a novel lateral mass screw and rod technique. Neurosurgery. 1999 Jun;44(6):1267-71, discussion:1271-2.

Taggard DA, Traynelis VC. Management of cervical spinal fractures in ankylosing spondylitis with posterior fixation. Spine (Phila Pa 1976). 2000 Aug 15;25(16):2035-9.

Wong AS, Massicotte EM, Fehlings MG. Surgical treatment of cervical myeloradiculopathy associated with movement disorders: indications, technique, and clinical outcome. J Spinal Disord Tech. 2005 Feb;18(14)(Suppl):S107-14.

Combination Anterior-Posterior Surgery

Kandziora F, Pflugmacher R, Scholz M, Schnake K, Putzier M, Khodadadyan-Klostermann C, Haas NP. Posterior stabilization of subaxial cervical spine trauma: indications and techniques. Injury. 2005 Jul;36(2)(Suppl 2):B36-43.

ElSaghir H, Böhm H. Anterior versus posterior plating in cervical corpectomy. Arch Orthop Trauma Surg. 2000;120(10):549-54.

Graham AW, Swank ML, Kinard RE, Lowery GL, Dials BE. Posterior cervical arthrodesis and stabilization with a lateral mass plate. Clinical and computed tomographic evaluation of lateral mass screw placement and associated complications. Spine (Phila Pa 1976). 1996 Feb 1;21(3):323-8, discussion:329.

Harrington JF Jr, Park MC. Single level arthrodesis as treatment for midcervical fracture subluxation: a cohort study. J Spinal Disord Tech. 2007 Feb;20(1):42-8.

Swank ML, Sutterlin CE 3rd, Bossons CR, Dials BE. Rigid internal fixation with lateral mass plates in multilevel anterior and posterior reconstruction of the cervical spine. Spine (Phila Pa 1976). 1997 Feb 1;22(3):274-82.

Wang MY, Levi AD. Minimally invasive lateral mass screw fixation in the cervical spine: initial clinical experience with long-term follow-up. Neurosurgery. 2006 May;58(5):907-12, discussion:907-12.

More than 15% of Patients Were Less Than Eighteen Years of Age

Anderson PA, Henley MB, Grady MS, Montesano PX, Winn HR. Posterior cervical arthrodesis with AO reconstruction plates and bone graft. Spine (Phila Pa 1976). 1991 Mar;16(3)(Suppl):S72-9.

Nazarian SM, Louis RP. Posterior internal fixation with screw plates in traumatic lesions of the cervical spine. Spine (Phila Pa 1976). 1991 Mar;16(3)(Suppl):S64-71.

Tumor Was the Sole Indication for Surgery

Bilsky MH, Boakye M, Collignon F, Kraus D, Boland P. Operative management of metastatic and malignant primary subaxial cervical tumors. J Neurosurg Spine. 2005 Mar;2(3):256-64.

Denaro V, Di Martino A, Papalia R, Denaro L. Patients with cervical metastasis and neoplastic pachymeningitis are less likely to improve neurologically after surgery. Clin Orthop Relat Res. 2011 Mar;469(3):708-14.

No Mention of Lateral Mass Screw Fixation

Haro H, Komori H, Okawa A, Shinomiya K. Surgical treatment of cervical spondylotic myelopathy associated with athetoid cerebral palsy. J Orthop Sci. 2002;7(6):629-36.

Mixed Surgical Population (Lateral Mass Screw Fixation and Wiring without Fixation), Results Not Reported Separately
Kuhns CA, Geck MJ, Wang JC, Delamarter RB. An outcomes analysis of the treatment of cervical pseudarthrosis with posterior fusion. Spine (Phila Pa 1976). 2005 Nov 1;30(21):2424-9.

Identical or Very Large Overlap in Populations
Audat ZA, Barbarawi MM, Obeidat MM. Posterior cervical decompressive laminectomy and lateral mass screw fixation. Neurosciences (Riyadh). 2011 Jul;16(3):248-52.

Cooper PR, Cohen A, Rosiello A, Koslow M. Posterior stabilization of cervical spine fractures and subluxations using plates and screws. Neurosurgery. 1988 Sep;23(3):300-6.

Sekhon LH. Posterior cervical decompression and fusion for circumferential spondylotic cervical stenosis: review of 50 consecutive cases. J Clin Neurosci. 2006 Jan;13(1):23-30. ■

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TABLE E-1 Safety Outcomes of Patients with Spondylosis, Trauma, or Mixed Diagnoses

Outcome	Studies	Demographics*	Follow-up† *(mo)*	Risk (95% CI) *(%)*
Local safety				
Surgical site complications				
Superficial infection†§	14[2,5,7,9,13,14,16,17,19,20,22-25]	n = 1111 Male, 61.0 (50-84)# Age, 55.1 (32-68)	20.7 (9-46)	2.9 (1.9-3.9)
Deep infection	7[5,7,9,13,20,23,25]	n = 680 Male, 61.8 (50-80) Age, 55.5 (41-68)	19.2 (9-28)	0.6 (0.1-1.2)
Hematoma/seroma‡	6[5,7,9,14,18,24]	n = 704 Male, 58.1 (51-68) Age, 58.9 (45-68)	20.3 (15-48)	1.0 (0.3-1.7)
Evacuation surgery for hematoma‡	4[5,7,14,24]	n = 454 Male, 60.1 (51-64) Age, 54.3 (45-61)	19.9 (15-25)	0.9 (0-1.7)
Dysphagia†	1[14]	n = 158 Male, 58.9 Age, 61.0	14.5 (3-72)	0.6 (0-1.9)
Neurological events				
Nerve root injury†§**	11[5,7-9,14,16,17,20,22,24,25]	n = 1041 Male, 62.2 (51-80)# Age, 55.4 (41-68)	19.5 (14-30)††	3.9 (2.8-5.1); due to screws, 1.0 (0.3-1.6)†‡
Dural injury/tear	3[5,7,9]	n = 478 Male, 57.9 (53-64) Age, 59.3 (45-68)	20.3 (18-24)	1.9 (0.7-3.1); due to screws, 0 (0-0.6)
CSF leakage	2[7,23]	n = 144 Male , 60.7 (50-64) Age, 47.5 (45-56)	17.7 (9-20)	1.4 (0-3.3); due to screws, 0 (0-2.1)
Neurological adverse events, unspecified§	6[2,7,17,18,22,25]	n = 404 Male, 73.7 (64-84)† Age, 46.6 (32-68)	23.3 (14-48)	0.3 (0-0.7)
Spinal cord injury	4[8,9,22,25]	n = 488 Male, 63.5 (53-80)# Age, 55.7 (41-68)	18.0 (14-24)††	0.4 (0-1.0); due to screws, 0 (0-0.6)
Other complications				
DVT/PE	2[2,7]	n = 154 Male, 69.7 (64-84) Age, 41.3 (32-45)	26.7 (20-46)	4.6 (1.3-7.8)
Death, any§§	6[2,5,7,9,16,24]	n = 603 Male, 59.8 (51-84) Age, 56.7 (32-68)	23.1 (18-46)	1.7 (0.6-2.7)
Stroke	1[7]	n = 110 Male, 64 Age, 44.8	20.4	0 (0-2.7)

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TABLE E-1 (*continued*)

Outcome	Studies	Demographics*	Follow-up† *(mo)*	Risk (95% CI) *(%)*
Vertebral artery injury	7[2,5,7,9,22,24,25]	n = 758 Male, 62.9 (51-84)# Age, 53.5 (32-68)	21.5 (14-46)	0 (0-0.4)
Lateral mass fracture##	3[7-9]	n = 405 (2829 screws) Male, 58.9 (53-70) Age, 57.6 (44-68)	18.8 (18-20)††	1.9 (1.4-2.5) of screws
	1[21]	n = 36 Male, 50 Age, NR, range 16-75	17 (9-60)	2.8 (0-8.2)
Hardware complications				
Screw/rod pullout§***†††	8[5,7-9,22-25]	n = 818 (5450 screws) Male, 61.7 (51-80)# Age, 53.9 (41-68)	19.5 (9-25)††	0.2 (0.1-0.4) of screws
	2[16,17]	n = 70 Male, 70.1 (66-75) Age, 66.3 (65-68)	23.3 (15-30)	10.0 (3.0-17.0)
Screw loosening##***	4[2,22,24,25]	n = 280 (1818 screws) Male, 74.7 (51-84)# Age, 43.5 (41-53)	23.4 (14-46)	0.8 (0.4-1.2) of screws
	1[21]	n = 36 Male, 50 Age, NR, range 16-75	17 (9-60)	16.7 (4.5-28.8)
Screw/plate breakage§***	6[5,7,9,22,24,25]	n = 714 (4827 screws) Male, 61.4 (51-80)# Age, 54.8 (41-68)	20.0 (14-25)	0.2 (0.1-0.3) of screws
	2[16,17]	n = 70 Male, 70.1 (66-75) Age, 66.3 (65-68)	23.3 (15-30)	5.7 (0.3-11.2)
Screw lucency	1[23]	n = 34 (267 screws) Male, 50 Age, 56.3	9	0.8 (0-1.8) of screws
Screw violating facet joint***	4[5,7,22,24]	n = 374 (2746 screws) Male, 60.7 (51-64)# Age, 51.2 (45-57)	22.8 (20-25)	0.6 (0.3-0.9) of screws
Screw violating vertebral foramen§***	5[5,7,8,23,24]	n = 400 (2715 screws) Male, 61.4 (50-70) Age, 50.0 (44-57)	21.4 (9-25)††	1.5 (1.1-2.0) of screws
	1[16]	n = 38 Male, 66 Age, 65	30.2	2.6 (0-7.7)
Screw violating spinal canal***	3[5,7,24]	n = 296 (2092 screws) Male, 60.7 (51-64) Age, 50.7 (45-57)	22.8 (20-25)	0 (0-0.1) of screws

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TABLE E-1 (*continued*)

Outcome	Studies	Demographics*	Follow-up† *(mo)*	Risk (95% CI) *(%)*
Subsequent surgery				
Revision: surgery that modified or adjusted the original implant because of signs and symptoms such as pain, radiculopathy, etc.§	5[2,7,9,13,17]	n = 435 Male, 61.5 (53-84) Age, 58.4 (32-68)	21.7 (15-46)	2.3 (0.9-3.7)
Hardware removal/ adjustment: surgery to correct malpositioned screws, screw breakout, or loosening†***	5[7,20,22-24]	n = 294 (2185 screws) Male, 58.5 (50-64)# Age, 48.0 (41-56)	21.3 (9-26)	1.2 (0.8-1.7) of screws
	2[14,16]	n = 196 Male, 60.4 Age, 61.8 (61-65)	17.5 (15-30)	1.0 (0-2.4)
Supplemental fixation: surgery to provide additional stabilization to the index site	1[22]	n = 78 Male, NR Age, 52.9	24.0 (10-47)	1.3 (0-3.8)
Reoperation: additional procedure at the index level other than a revision, hardware removal, or supplemental fixation†††	9[2,5,7,9,15,20,22-24]	n = 721 Male, 58.9 (50-84)#§§§ Age, 55.2 (41-68)###	22.7 (9-46)	3.7 (2.4-5.1)

*The values for the percentage of male patients are given as the mean, with the range of values in the individual studies in parentheses. The values for the age in years are given as the mean, with the range of means in the individual studies in parentheses. NR = not reported. †The values are given as the mean, with the range of values in the individual studies in parentheses. ‡Eubanks[14] was a comparative study designed to assess the impact of smoking on fusion rates in posterior cervical fusion with lateral mass instrumentation; 26% (41/158) of the entire population were smokers. §In one study (Huang[17]), 78% of patients had substantial comorbidities. #The percentages of male and female subjects were not reported in one study (Heller[22]). **To include radiculopathy, nerve root palsy, and nerve root pain. ††Mean follow-up duration was not reported in one study (Katonis[8]). ‡‡In two studies (Eubanks[14] and Houten[16]), it was unclear whether the complications (seven and one nerve root injuries, respectively) arose from the screws or the decompression, and thus these were left out of the ''due to screws'' risk estimate. §§Due to two massive PEs, two malignancies, two cases of pneumonia and respiratory failure, one intraoperative cerebrovascular accident not attributed to lateral mass fixation/surgery, one posttraumatic vertebral artery dissection not attributed to lateral mass fixation/surgery, one small intestinal perforation from preexisting Crohn disease resulting in sepsis, one cardiovascular medical problem at 20 mo postop., and one complication related to human immunodeficiency virus infection. ##For Ebraheim[21] (n = 36), in a patient with osteoporosis and tumor involvement resulting in massive destruction of vertebral body and lamina. ***One study (Wellman[24]) included 22 C7 pedicle screws. †††In one study (Wu[25]), the only screw backout occurred in a patient who developed kyphotic deformity resulting in self-pullout of the screws. ‡‡‡To include surgery for adjacent segment degeneration, evacuation of hematoma, CSF leakage, and anterior cervical stabilization. §§§One study (Highsmith[15]) did not report the percentages of male and female subjects. ###Mean age was not reported separately for the subgroup of patients (15/26) who underwent cervical-only lateral mass plating in one study (Highsmith[15]).

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TABLE E-2 Characteristics of All Studies*

Study	Study Design	Demographics†	Diagnoses	Interventions	Follow-up
Comparative					
Lowry[12]	Retrospective comparative	N = 48 Bands, n = 34 Male, 50.0% Age†, 39.4 (18-76) Plates, n = 14 Male, 93.0% Age, 54.0 (22-78)	Etiology§ DDD Bands, n = 11 (32.4%) Plates, n = 3 (21.4%) Trauma Bands, n = 18 (52.9%) Plates, n = 7 (50.0%) Prior operation Bands, n = 2 (5.9%) Plates, n = 3 (21.4%) RA Bands, n = 1 (2.9%) Plates, n = 2 (14.3%) Metastatic cancer Bands, n = 1 (2.9%) Plates, n = 0 Unknown Bands, n = 1 (2.9%) Plates, n = 0 Preop. status Intact Bands, n = 6 (17.6%) Plates, n = 3 (21.4%) Neck pain only Bands, n = 13 (38.2%) Plates, n = 0 Radiculopathy Bands, n = 7 (20.6%) Plates, n = 2 (14.3%) Myelopathy Bands, n = 8 (23.5%) Plates, n = 9 (64.3%)	Tension band wiring Lateral mass plating Mean levels fused: Bands: 1.7 (range, 1-4) Plates: 1.7 (range, 1-3) Postop. immobilization with collar only: Bands: n = 28 (82%) Plates: n = 11 (79%)	Bands: mean, 1.9 yr (range, 0.3-4.7 yr); 94% (32/34) followed Plates: mean, 2.9 yr (range, 1.8-3.9 yr); 100% (14/14) followed
Shapiro[11]	Retrospective comparative	N = 51 Anterior cervical discectomy and fusion using posterior interspinous braided cable with lateral mass plate, n = 5 Male, 83.6% Age, 30 (19-52)	Unilateral locked cervical facets Radiculopathy, n = 37 (73%) Neck pain but neurologically normal, n = 8 (18%) Incomplete spinal cord injury, n = 6 (12%)	Spinous process wire fixation and facet wiring to struts of iliac crest (n = 24); 2 or 3-level fusion in 20 cases Interspinous wiring with braided cable for lateral mass plating (n = 22); local and allogenic bone graft; 2 or 3-level fusion in 21 cases Level of facet dislocation: C5-C6, 41% C6-C7, 25% C3-C4, 17% C4-C5, 17%	Range, 1-10 yr Mean follow-up: Wire/facet wiring group: 8.5 yr Wire/cable for lateral mass plating group: 3.3 yr 1-yr follow-up: 84.8% (39/46) Wire/facet wiring group: 75.0% (18/24) Wire/cable for lateral mass plating group: 95.5% (21/22)

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TABLE E-2 (*continued*)

Study	Study Design	Demographics†	Diagnoses	Interventions	Follow-up
Case Series					
Al Barbarawi[7]	Case series	N = 110 Male, 63.6% Age, 44.8 (16-74)	DDD, mainly degenerative spondylotic myelopathy, n = 73 (66.3%) Trauma, n = 23 (20.9%) Tumor, n = 4 (3.7%) Metabolic or inflammatory disease, n = 4 (3.7%) Congenital anomalies, n = 6 (5.4%)	Posterior decompressive cervical laminectomy and lateral mass screw fixation using the Anderson-Sekhon technique Screws angulated into the lateral mass based on modified Anderson and Sekhon techniques Levels fixed: C3-C6, n = 39 (35.5%) C3-C5, n = 9 (8.3%) C4-C6, n = 38 (34.5%) C3-C7, n = 10 (9.2%) C4-C7, n = 4 (3.7%) C5-C7, n = 3 (2.8%) Craniocervical, n = 6 (5.6%) Cervicothoracic incorporation, n = 1 (0.9%) Postop., all patients were placed in a hard neck collar	Mean, 1.7 yr (range, 0.3-3 yr) Percent followed: NR
Cabraja[13]	Case series, 1 arm of a comparative study	N = 24 Male, 70.8% Age, 66.2 ± 8.8 (45-84)	Multilevel cervical spondylotic myelopathy Spondylosis, n = 17 (71%) OPLL, n = 7 (29%) All patients refractory to conservative treatment	2 to 4-level, C3-C7 laminectomy followed by posterior instrumentation with lateral mass screws Local autograft used	Mean, 28 mo (range, 15-67 mo) Percent followed: NR
Ebraheim[21]	Case series	N = 36 Male, 50% (18/36) Age, NR (16-75)	Unilateral facet dislocation, n = 12 Ligamentous instability, n = 7 Burst fracture, n = 3 Bilateral facet dislocation, n = 2 Teardrop fracture, n = 2 Tumor, n = 6 Postlaminectomy spondylotic myelopathy, n = 4 Preoperative neurological deficits were present in 12 patients with posttraumatic instability and 2 with bone metastasis	Posterior stabilization using stainless steel Roy-Camille Spinal Plates, A/O reconstruction plates, or, more recently, titanium plates and screws Autogenous iliac crest bone graft was used in all but one patient All but 2 patients had a cervicothoracic brace fitted postop. and worn constantly, even in bed, for 3 mo One patient required a halo brace because of Parkinson disease A second patient who had one plate and interosseous wire also used a halo brace for additional stability	Mean, 17 mo (range, 9-60 mo) 97% (35/36) followed until clinical and radiographic union was achieved

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TABLE E-2 (*continued*)

Study	Study Design	Demographics†	Diagnoses	Interventions	Follow-up
Eubanks[14]	Case series	N = 158 Male, 59% (93/158) Age, 61 (35-87)	Primary diagnosis of stenosis, n = 138 Primary diagnosis of radiculopathy or pseudarthrosis, n = 20 Secondary and tertiary diagnoses: Myelopathy, n = 36 Radiculopathy, n = 72 Myeloradiculopathy, n = 46 Nonunion, n = 37	Posterior fusion alone, n = 13 Foraminotomy and fusion, n = 8 Posterior fusion and laminectomy, n = 137 All posterior cervical fusions involved lateral mass instrumentation, decortication of facet joints and lateral masses, and placement of iliac crest bone graft Patients were placed in a hard cervical collar for 3 wk and then transitioned to a soft collar for another 3 wk as needed	Mean, 14.5 mo (range, 3-72 mo)
Fehlings[2]	Case series	N = 44 Male, 84.1% Age, 32.4 (16-80)	Posttraumatic instability due to trauma, n = 42 Cervical discitis/ osteomyelitis, n = 1 Cervical spine plasmacytoma, n = 1 All patients judged to have instability of the cervical spine by clinical and radiographic criteria including neck pain, neurological deficit, abnormal sagittal plane translation, or kyphosis	Fixation of the lateral masses of the subaxial cervical spine with posterior screw-plate constructs Levels fixed: 2, n = 23 (C3-C4, n = 1; C4-C5, n = 8; C5-C6, n = 9; C6-C7, n = 5) 3, n = 21 (C3-C5, n = 4; C4-C6, n = 13; C5-C7, n = 4) During the first 3 yr of the study, Roy-Camille plates fashioned from Vitallium were used; during the last year, titanium universal bone plates were used All patients were mobilized postop. in a Philadelphia collar for 3 mo	Mean, 3.8 yr (range, 2-6 yr) 93.2% (41/44) followed
Heller[22]	Case series	N = 78 Male, NR Age, 52.9 (14-82)	Cervical spondylosis, n = 37 Cervical radiculopathy, n = 29 Cervical instability, n = 23 Cervical stenosis, n = 22 Cervical myelopathy, n = 22 Nonunion, n = 15 Fracture/dislocation, n = 11 Tumor, n = 10 Kyphosis, n = 9 OPLL, n = 7 Herniated nucleus pulposus, n = 5 Basilar invagination, n = 3 Klippel-Feil, n = 2 Diffuse idiopathic skeletal hyperostosis, n = 1 DDD, n = 1	Followed technique by An et al. Posterior cervical lateral mass plating Titanium plates were used in 72 cases, including 25 Synthes plates and 47 AXIS plates Iliac crest autograft was used in 74 of the patients in whom fusion was attempted 4 patients with metastatic lesions did not undergo fusion because of their short life expectancy	Mean, 2 yr (range, 10-47 mo) Follow-up percentage, NR

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TABLE E-2 (*continued*)

Study	Study Design	Demographics†	Diagnoses	Interventions	Follow-up
				Supplemental wire fixation was used in only one case 9 patients (11.5%) were judged to require halo immobilization; otherwise, all patients were treated with a rigid cervical collar or 2-post cervical thoracic orthosis	
Highsmith[15]	Case series, 1 arm of a comparative study; 15 patients meeting our inclusion criteria used in analysis	N = 26 Male, NR Age, 58 (42-81)	Cervical stenotic myelopathy	Cervical laminectomy with posterior fusion with lateral mass screw-rod fixation and autologous iliac crest Mean no. of operated levels, 5.3 (range, 3-8)	Mean, 41.3 mo (range, 12-85 mo)
Houten[16]	Case series	N = 38 Male, 66% (25/38) Age, 65 (41-86)	Spinal cord compression caused by OPLL at ≥2 vertebral levels, n = 7 (18%) Cervical spondylosis at ≥3 motion segments, n = 29 (76%) Myelopathy, n = 38 (100%)	Multilevel cervical laminectomy and immediate stabilization with lateral mass plates Holes were drilled in the lateral masses bilaterally with the technique described by Magerl and Seeman A cervical collar was used for patient comfort for 2 to 8 wk	Mean, 30.2 mo (range, 6-100 mo) 100% (38/38) followed for min. 6 mo
Huang[17]	Case series	N = 32 Male, 75% (24/32) Age, 67.8 (50-79)	Cervical myelopathy with radiculopathy Multilevel cervical spondylotic myeloradiculopathy, n = 28 OPLL, n = 4 Myelomalacia, n = 15 Multilevel cord compression (with a mean of 4.8 levels, range 3-6 levels), n = 32	Multilevel cervical myelopathy treated by laminectomy and posterior lateral mass plate fusion Lateral mass screw and plate instrumentation was performed in each case using the Axis Fixation System Local bone was used as graft in all cases and was augmented with Grafton demineralized bone matrix as required Postop., patients were immobilized in a Miami-J collar for six wk	Mean, 15.2 mo 97% (31/32) followed for min. 6 mo
Katonis[8]#	Case series	N = 70 Male, 70% (49/70) Age, 44 (19-75)	Cervical myelopathy, n = 19 Instability (posttraumatic/degenerative), n = 14 Facet/laminar fracture (instability/subluxation), n = 16 Pure facet subluxation (perched), n = 7 Failed anterior fusion, n = 7 Tumor/amyloidosis, n = 5 Post-infection reconstruction, n = 2	Posterior subaxial (C3-T2) lateral mass fixation Type I fusion: plates with no bone graft (facets were scraped/decorticated), n = 7 Type II fusion: plates with intrafacet graft plus graft under/adjacent to plates, n = 47 Type III fusion: plates with intrafacet graft and unicortical slabs affixed to spinous processes by interspinous titanium cable, n = 16	Mean, NR (range, 2-7 yr) 100% (70/70) followed for min. 2 yr

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TABLE E-2 (*continued*)

Study	Study Design	Demographics†	Diagnoses	Interventions	Follow-up
				Lateral mass screw placement at cervicocervical (C3-C6) levels was performed in 62 (88.6%) of 70 patients; the remainder (11.5%) had cervicothoracic fusion Cervicothoracic constructs incorporated C7, T1, or T2 and used pedicle screws instead of lateral mass screws	
Katonis[9]#	Case series	N = 225 (1662 screws) Male, 53% (120/225) Age, 68 (45-84)	Cervical myelopathy, n = 225	Posterior cervical laminectomy and fixation using 1662 lateral mass screws placed free-hand in a subaxial position (C3-C6) C3-C5 placement, n = 26 C3-C6, n = 156 C4-C6, n = 43 Unicortical placement, n = 1296 screws Bicortical placement, n = 366 screws Screw length: 10-16 mm In patients in whom short segmental fixation (C3-C5 and C4-C6) was performed, a short, soft neck collar was applied after surgery for 2-3 wk A Philadelphia collar was applied for 2-3 mo in patients with severe osteoporosis and in patients who had fixation of 3 motion segments (C3 to C6) More rigid postop. external supports including halo vest immobilization were not used	Mean, 18 mo (range, 12-72 mo) 100% (225/225) followed for min. 12 mo
Kumar[18]	Case series	N = 25 Male, 68% (17/25) Age, 60 (33-79)	Cervical spondylotic myelopathy, n = 25; myelopathy index: Grade II, n = 6 (24%) Grade IIIa, n = 12 (48%) Grade IIIb, n = 4 (16%) Grade IV, n = 3 (12%)	Posterior cervical laminectomy and fusion/fixation with lateral mass plates Laminectomy and fusion were performed at 3 levels in 3 patients, 4 levels in 11 patients, 5 levels in 10 patients, and 6 levels in 1 patient	Mean, 47.5 mo (range, 25-82 mo) 100% (25/25) followed for min. 2 yr

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TABLE E-2 (*continued*)

Study	Study Design	Demographics†	Diagnoses	Interventions	Follow-up
Liu[19]	Case series	N = 38 Male, 23.7% Age, 45 (24-60)	Pseudarthrosis after ACDF All had symptoms of neck pain with or without arm pain, weakness, numbness, and headache	Posterior lateral mass screw fixation (multiaxial screw-rod or plate systems) from C3-C7 (1 patient had extension to T1) Decompressive laminectomy or foraminotomy (n = 34)	Mean, 28 mo (range, 24-60 mo) 100% followed
Pateder[20]	Case series	N =34 Male, 59% (17/29) Age, 41 (18-85)	Motor vehicle collision, n = 23 Fall, n = 4 Work-related accident, n = 2 Vertical compression (burst fracture), n = 7 Distractive flexion (dislocation), n = 3 Compressive flexion (tear drop fracture), n = 3 Unilateral (n = 6) and bilateral (n = 5) facet fracture and/or dislocation Lateral mass fracture, n = 4 Pedicle fracture, n = 1 Lamina fracture, n = 1	Posterior spine fusion and lateral mass instrumentation All 198 screws were placed via a modified An technique and intraoperative fluoroscopic confirmation Pedicle screws were routinely placed at C7 by the Carbone et al. technique All patients were placed in a neck collar until the 6-wk follow-up	Mean, 26 mo (range, 24-48 mo) 85% (29/34) followed for min. 24 mo
Sekhon[5]	Case series	N = 143 (1026 screws) Male, 61% (87/143) Age, 56.8 (12-96)	Trauma, n = 35 Degenerative disease, n = 92 Iatrogenic instability, n = 4 RA, n = 3 Malignant spinal tumor, n = 6 Benign spinal tumor, n = 2	Posterior cervical lateral mass screw fixation All screws were placed by a modification of the Anderson technique, but 20 screws were converted to Roy-Camille trajectories because of screw pullout Instrumentation was used in cases where instability was present or where wide decompression would lead to instability A variety of different implants were used, including Axis and Cervifix plates and screws and Vertex, Summit, Oays, and Starlock polyaxial screw/rod constructs Standard Sekhon trajectory, n = 1006 screws Rescue Roy-Camille trajectory, n = 20 C7 lateral mass screws, n = 94 C7 pedicle screws, n = 4	Mean, 22.04 mo (range, 1-50 mo) ''No living patients lost to follow-up''

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TABLE E-2 (*continued*)

Study	Study Design	Demographics†	Diagnoses	Interventions	Follow-up
				Patients were monitored overnight and were placed into an Aspen collar postop.	
Stevens[23]	Case series	N = 34 Male, 50% Age, 56.3 (39-83)	Spondylosis, n = 15 (44%) Pseudarthrosis, n = 13 (38%) Trauma, n = 3 (9%) Instability from bone metastasis, n = 2 (6%) Infection (discitis), n = 1 (3%)	Posterior instrumentation with lateral mass screw placement from C3 to C7	Mean, 9 mo (range, 1-30 mo) 76.5% (26/34) followed
Wellman[24]	Case series	N = 43 Male, 51.1% Age, 45.5 (19-81)	Trauma, n = 24 Spondylosis, n = 13 Kyphosis, n = 4 OPLL, n = 1 Tumor, n = 1	Posterior cervical fusion with an articular mass plate fixation system Technique similar to that of An et al. 259 screws were placed in the lateral masses of the cervical spine, whereas 22 were placed into the pedicles of C7	Mean, 25 mo (range, 1-63 mo) 81% (35/43) followed
Wu[25]	Case series	N = 115 Male, 80% (92/115) Age, 40.63 (18-82)	Trauma, n = 56 Myelopathy/radiculopathy, n = 49 Neoplasm, n = 8 Other, n = 2	Posterior fixation surgery Lateral mass screw placement at various levels in the subaxial cervical spine, from C3 to C7: C3, 129 screws C4, 115 screws C5, 193 screws C6, 101 screws C7, 135 screws Polyaxial screws and rods were used for every patient The posterior lateral aspects of the lateral masses underwent decortication for osseous fusion with autologous bone grafts mixed with demineralized bone matrix Modified Magerl technique Postop., patients were recommended to wear a Miami-J cervical collar for at least 6 wk	Mean, 14 mo (range, 4-35 mo) Follow-up percentage: NR

*DDD = degenerative disc disease, RA = rheumatoid arthritis, NR = not reported, OPLL = ossification of the posterior longitudinal ligament, A/O = Arbeitsgemeinschaft für Osteosynthesefragen, and ACDF = anterior cervical discectomy and fusion. †Ages are presented in years as the mean, with the range in parentheses. †Age reported by group only for those followed, n = 32. §The total for plates is 15 rather than 14 because of a discrepancy between Tables I and II in Lowry[12]. #Probable small overlap in populations in the Katonis studies[8,9].

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TABLE E-3 Results in the Comparative Studies and Case Series*

Study	Clinical Outcomes	Radiographic Outcomes	Safety
Comparative			
Lowry[12]	Postop. status: Worse: Bands: 0 Plates: 0 Improvement or resolution of symptoms: Bands: 78.6% (22/28) Mechanical neck pain: 84.6% (11/13) Radiculopathy: 100% (7/7) Myelopathy: 50% (4/8) Plates: 90.9% (10/11) Radiculopathy: 100% (2/2) Myelopathy: 88.9% (8/9)	Fusion: Bands: 96.9% (31/32) Plates: 100% (14/14)	Pseudarthrosis: Bands: 3.1% (1/32) Plates: n = 0 Loss of reduction: Bands: 6.3% (2/32) Plates: n = 0 Infection: Bands: 3.1% (1/32) (graft site) Plates: n = 0 Wound seroma: Bands: n = 0 Plates: 7.1% (1/14) Wire/screw breakage: Bands: 3.1% (1/32) Plates: n = 0 Wire/screw loosening: Bands: n = 0 Plate: 3.9% (n = 3/76 screws placed) Reoperation: Bands: 6.3% (n = 2/32) (hardware removal) Plate: n = 0
Shapiro[11]	Neurological worsening, n = 0 in either group Substantial persistent neck pain that interfered with daily activities and required analgesic therapy: Wire and facet wire/iliac crest group, 17% (4/24) Cable and lateral mass plate group, 9% (2/22)	Perfect alignment with sustained cervical lordosis at 1 yr postop.: Wire and facet wire/iliac crest group, 46% (11/24) Cable and lateral mass plate group, 64% (14/22) The braided cables and lateral mass plates were better at achieving and sustaining reduction and lordotic alignment, and the amount of kyphosis, when present, was significantly less ($p < 0.02$)	No failures in either group No long-term cable breakage, screw backout, or other instrument breakage in the lateral mass plating group Reoperation via anterior approach for resubluxation: Wire fixation: 1/24 Plate: n = 0
Case series			
Al Barbarawi[7]	NR	NR	Postop. complications: Vertebral artery injury, n = 0 Nerve root damage, n = 0 Neurological deterioration, n = 0 Stroke, n = 0

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
			Dural tears requiring intraoperative repair, 5.5% (6/110) Reoperation due to poor screw placement, 1.8% (14/785 screws) Persistent C5 nerve root pain, 13.6% (15/110) Revision, n = 1 (nerve root pain/malposition) Superficial infection, 5.6% (6/110) Deep infection, n = 0 CSF leakage, 0.9% (1/110) Lateral mass fracture/ breakout, 14/785 screws Screw or rod pullout/ breakage, 0/505 screws Screws violating facet joint, 1.1% (8/785 screws) Screws violating vertebral foramen, 0.6% (5/785 screws) Screws violating spinal canal, 0% (0/785 screws) ASD requiring surgery, n = 0 Hematoma requiring evacuation, n = 0 DVT, 3.6% (4/110) PE, 0.9% (1/110) Death, 0.9% (n = 1/110) (patient with massive PE) Complications at late/long-term follow-up (up to 3 yr): No cases of instrumentation failure, ASD, or vascular or neural damage
Cabraja[13]	VAS pain: Preop.: 4.4 ± 1.1 12 mo: 3.5 ± 1.0 Last f/u: 3.6 ± 0.9 P < 0.001 (preop. vs. last f/u) mJOA scale score: Preop.: 11.7 ± 3.2 12 mo: 14.3 ± 2.8 Last f/u: 14.9 ± 3.2 P < 0.001 (preop. vs. last f/u)	NR (alignment only)	Epidural bleeding, n = 2 (8.3%) Surgical revision, n = 2 (8.3%) (same patients with epidural bleeding) Wound infection, n = 1 (4.2%) CSF fistula, n = 1 (4.2%)

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
	Odom criteria: Excellent: 54.2% (n = 13) Good: 29.2% (n = 7) Fair: 16.7% (n = 4) Poor: n = 0		
Ebraheim[21]	All patients experienced good to excellent pain relief 33% (9/27) with neurological deficits recovered completely 56% (15/27) recovered partially 4% (1/27) made no recovery 4% (1/27) had progressive neurologic deficit requiring posterior decompression and fusion	Use of titanium implants allowed better CT and MRI scanning than use of stainless steel implants Loosening of short unicortical screws in the series, n = 6: 1 had osteoporosis and massive destruction of the vertebral body and lamina due to tumor involvement Of the other 5 patients, 1 had substantial osteoporosis and 2 had maldirection of a screw contributing to poor screw purchase	Successful fusion occurred at ~3 mo (range, 10-16 wk)
Eubanks[14]	80% (126/158) demonstrated an excellent or good result as graded by the Odom criteria 20% (32/158) displayed a fair or poor result Insufficient numbers to draw any conclusions regarding associations between clinical outcome scores and comorbidities, Workers' Compensation status, or the amount of nicotine used	Insufficient numbers existed in surgical subgroups for comparison of posterior fusion (n = 13) alone with foraminotomy plus fusion (n = 8) or laminectomy plus fusion (n = 137) No patients with symptomatic ASD required subsequent surgery during the f/u period	Complications included 7 C5 nerve root palsies (4 in smokers, 3 in nonsmokers); all recovered uneventfully One hardware failure in the early postop. (3- wk) period, revised without further complication Infected iliac crest wound, n = 4 Hematoma, n = 1 (requiring irrigation and debridement) Bowel perforation and femoral neck fracture, n = 1 Postop. dysphagia (unrelated to the surgical procedure), n = 1
Fehlings[2]	Sensorimotor function on ASIA Impairment Scale† (n = 35 patients with preop. and final f/u scores): Improved, 25.7% (9/35) Same, 74.3% (26/35) Worse, n = 0 Chronic substantial neck pain (requiring analgesics or interferes with ADLs), 5.2% (2/38)	Fusion (>6 mo postop.): Overall fusion rate: 92.7% (38/41) Patients without bone-grafting: 91.2% (31/34) Patients with bone-grafting: 100% (7/7) NS difference between grafting and no grafting Correction of sagittal plane kyphosis: Mean preop.: 24.4° ± 3.2° Mean postop.: 5.0° ± 6.4° Mean correction: 19.4° ± 5.5° P < 0.001	Perioperative: Death, n = 0/44 Neurological deterioration, 0/44 Vascular complications, 0/44 Revision, 6.8% (3/44) Superficial infection, 4.5% (2/44) DVT, 4.5% (2/44) Sacral decubitus, 4.5% (2/44) Renal sepsis, 2.3% (1/44) Occipital decubitus, 2.3% (1/44)

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
			Longer-term (>2 yr) f/u: Loose screws, 3.8% (8/210 screws) Extension of fusion beyond instrument segments, 5.3% (1/38) Chronic substantial neck pain (requiring analgesics or interferes with ADLs), 5.3% (2/38) Increased kyphosis, 5.3% (2/38) 2 patients died at 4 and 9 mo of chronic medical problems not related to the surgery
Heller[22]	SSEPs were monitored during 74/78 (95%) of the procedures Intraoperative SSEP changes occurred in 10 (14%) of the patients: 9 patients improved 1 patient worsened	Follow-up flexion-extension radiographs of the 71 patients who underwent fusion showed only one apparent pseudarthrosis (1.4%), which was asymptomatic Asymptomatic facet joint violation noted on f/u radiograph, n = 1	Immediate complications directly attributable to lateral mass screw insertion occurred in 7 patients (9%) Acquired radiculopathies were observed in 6 patients: In 4 of the 6 patients, the deficit appeared to result from either a screw that was too long or the drilling technique Additional surgery for screw removal, exchange, or foraminotomy was required for these 6 cases Screw avulsion with loss of reduction occurred in 1 patient 2 wk after discharge, resulting in a mild central cord syndrome 3 patients (3.8%) who complained of neck pain after surgery were found to have adjacent segment degeneration within 2.5 yr of surgery; 2 required additional surgery 2 patients (1.3%) developed a superficial wound infection Implant failures: one broken plate and two broken screws; only one patient required additional surgery for screw replacement No spinal cord or vertebral artery injuries attributable to screw insertion 2 spinal cord injuries (2.6%) due to causes other than screw insertion 1 anterior horn cell infarct

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
Highsmith[15]	N/A	N/A	Subgroup analysis done for the reoperation rate in the 15 patients (58%) without C7 fusion extending to T1: 13.3% (2/15)
Houten[16]	mJOA scale: Improvement occurred in 97% (37/38) Mean scores improved from 12.9 preop. to 15.58 postop. ($p < 0.0001$) Symptom duration and age did not correlate with the presenting mJOA scores or magnitude of mJOA improvement after surgery Patients with sphincter dysfunction had lower mean mJOA scores at presentation than those with intact sphincter function (10.4 vs. 13.3; $p < 0.0089$), but did not differ in magnitude of recovery Cooper scale scores: For upper extremities, improved from 1.8 preop. to 0.7 postop. ($p < 0.0001$) For lower extremities, improved from 1.0 to 0.4 ($p < 0.0002$) Muscle weakness In muscles with less than normal function preop., neurological improvement was noted in 96% of muscles (139/145) Preop. vs. postop. mean scores for muscles with preop. weakness: 3.68 vs. 4.74 for hand intrinsics 4.04 vs. 4.96 for triceps 3.93 vs. 4.79 for iliopsoas	Unilateral screw backout, n = 4 Bilateral screw backout, n = 1 Unilateral broken screws, n = 3 Plate breakage, n = 0 Plate pull-away from the lateral masses, n = 0 Mean preop. compression grade for all patients was 2.46, whereas mean postop. grade was 0.16 ($p < 0.0001$) No radiographic evidence of compression from scar tissue posterior to the spinal cord in any patient	Death 20 mo after surgery from cardiovascular medical problems, n = 1 Death 21 mo after surgery from complications related to human immunodeficiency virus infection, n = 1 Reoperation to reposition a screw penetrating the C5-C6 neural foramen, n = 1 Postop. pneumonia, n = 1 Superficial wound infection, n = 1 Unilateral C5 root palsy that resolved completely over several mo, n = 1
Huang[17]	Nurick grade† Mean preop. score: 2.6 (range, 1-4) Mean at final f/u: 1.8 (range, 0-3) 71% (22/31) had improvement of at least one point	All patients had postop. MRI scanning at a mean 3.8 mo postop. Residual low-grade cord compression, n = 1 All patients achieved radiographic fusion at final f/u, although one patient required a second procedure to achieve fusion	Postop. wound infection, n = 3 Neurological deterioration, n = 0 Chronic infection, n = 0 Unilateral shoulder pain and weakness attributed to C5 traction radiculopathy, n = 2 Postop. confusion resulting in delayed discharge from the hospital, n = 2

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
	29% (9/31) had no improvement No patients had deterioration Mean improvement of all patients: 0.81 point ($p < 0.0001$) Patients with higher preop. scores had a higher probability of experiencing postop. score improvement Patients with preop. myelomalacia improved a mean of 0.80 point Patients without preop. myelomalacia improved a mean of 0.81 point No significant effect of preop. myelomalacia on Nurick grade recovery ($p = 0.64$) Neither age nor duration of symptoms significantly affected postop. improvement in Nurick grade	Despite successful radiographic fusion, two patients had backout of one or more screws and one had screw breakage	New-onset atrial defibrillation that spontaneously reverted to normal sinus rhythm in the hospital, n = 1
Katonis[8]	Most patients characterized their postop. pain as mild Most patients were able to use only nonnarcotic analgesics for pain relief	Screw trajectories within 15°-25° rostral in the sagittal plane and 20°-30° lateral to midline in the axial plane in 260 (73%) of the 356 screw placements Unicortical purchase was achieved in 206 (58%) of 356 screw placements Bicortical purchase was achieved in the remaining 150 screw placements 5 patients (7%) had a single lateral mass screw that penetrated the foramen transversarium Overall fusion rate: 91.5% (64/70) 8.5% fusion failure rate 4 of the 6 fusion failures occurred in patients who received no bone graft (type I fusion) Successful fusion in 46/47 patients (98%) with type II fusion Successful fusion in 15/16 patients (94%) with type III fusion	Screw pullout developed in 2 patients (3%) as a result of severe osteoporosis No cases of procedure-related radiculopathy 14/356 (4%) of screws caused fracture of the lateral mass

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
Katonis[9]	Motor weakness of the deltoid muscle after surgery, n = 5 Most patients characterized their postop. pain as mild Most patients were able to use only nonnarcotic analgesics for pain relief	11 screws (0.7%) had a suboptimal trajectory with no resulting vascular or neurological sequelae Screws with a sagittal angulation of <15° were associated with a risk of screw thread impingement on the exiting nerve root Screw holes with axial trajectories >30° lateral to midline usually caused no neurological harm but carried a risk of lateral mass fracture or screw ''cutout'' Overall fusion rate: 97.4% (219/225)	Fracture of the lateral mass occurred during placement of 27 screws (1.6%) and was not associated with neurovascular impairment Using bicortical screws, 3 patients (1.3%) experienced a radiculopathy and screw removal was necessary Substantial postop. wound hematoma, n = 2 Screw pullout, n = 3 Pseudarthrosis, n = 6 (after 6-12 mo) Reoperation required in 14 cases (6.2%) because of nerve injury, hematoma formation, pseudarthrosis, and screw pullout No cases of vertebral artery injury, spinal cord injury, dural tears, superficial or deep infection, progressive degenerative change at the adjacent mobile segments, hardware breakage, or death
Kumar[18]	80% of patients (20/25) had good outcomes (myelopathy Grade IIIa or better and hand function) 20% of patients (5/25) had poor outcomes No patient demonstrated neurological deterioration from the good to the poor outcome group during f/u period Myelopathy scores improved after surgery for 76% of patients (n = 19) and remained stable for 24% (n = 6) Patients who initially had myelopathy of Grade IIIa or better showed a significant improvement in their grades at f/u (p < 0.0001) Those who initially had myelopathy of Grade IIIb or worse did not demonstrate a significant change in their myelopathy grades (p < 0.08)	Minimal kyphosis preop., n = 4 Minimal kyphosis postop., n = 1 S-shaped spinal curvature preop., n = 2 S-shaped spinal curvature postop., n = 2 (no change) No progressive kyphosis and no instability on flexion/extension above or below the fusion during f/u period Minimal compression at the inferior C2 laminar level, n = 1 Hyperintense lesions noted in 60% (n = 3) of the patients with poor outcomes, as compared with 35% (n = 7) of those with good outcomes (p < 0.64) Cord atrophy observed in one patient with a poor outcome	Epidural hematoma causing neurological symptoms on the third postop. day, n = 1 Urinary tract infection requiring treatment with oral antibiotics, n = 1

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
	18 patients (72%) had preop. grades of IIIa or better, and at f/u, none had deteriorated Of the 7 patients (28%) who initially had myelopathy of Grade IIIb or worse, 4 (16% of total) improved and 3 (12%) remained the same; none deteriorated SF-36 questionnaire revealed a significant occurrence of depression in the poor outcome group ($p < 0.02$) but no difference between the outcome groups in social functioning ($p < 0.85$)		
Liu[19]	Clinical result (Zdeblick et al. criteria): Excellent, n = 10 (26.3%) Good, n = 22 (57.9%) Fair, n = 6 (15.8%) Poor, n = 0	Fusion rate: 100% (38/38) at final f/u	Superficial wound infection, n = 3 (7.9%) Bone graft site prolonged drainage, n = 1 (2.6%)
Pateder[20]	NR	28/29 patients (96.6%) had a mean change of 2° (range, 0°-6°) in sagittal alignment from the immediate postop. to the most recent f/u 1/29 had instrumentation/fixation failure and loss of sagittal alignment 3 mo postop. secondary to noncompliance 12/29 patients had 3 or more levels fused; these patients had a mean postop. change of 2.4° Patients with 2 or fewer levels fused had a mean postop. change of 1.7°	Unilateral C5 injury, n = 1 Superficial would dehiscence, n = 3 Deep wound infection, n = 1
Sekhon[5]	Preop. Nurick grade (of 94 cases) = 2.3 ± 1.2 Postop. Nurick grade (of 94 cases) = 1.01 ± 0.5	Instrumentation failure, n = 2 Kyphosis, n = 3 patients 92.4% of screws were bicorticate 20 screws (1.9%) breached the foramen transversarium by 0-1 mm No screw violated the foramen transversarium by >1 mm No case entered the neural foramen or canal 8 screws violated the inferior facet joint (typically at the C7 level)	Root injury due to screws, n = 0 Vertebral artery injury, n = 0 Dural tear, n = 3 Blood transfusion, n = 8 Superficial infection, n = 4 Deep infection, n = 1 Screw pullout, n = 6 (of 1026 screws) Screw breakage, n = 4 (of 1026 screws) Plate/rod breakage, n = 1 patient Death, n = 4

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
Stevens[23]	NR	Fusion at >6 mo (n = 16): 100%	C5 root injury, n = 1 Adjacent segment requiring surgery, n = 1 Hematoma requiring evacuation, n = 1 CSF leakage: n = 1 (2.9%; required reoperation) Hardware removal due to persistent pain: n = 2 (5.9%) Reoperation for dislodged rod from C3 screw: n = 1 (2.9%) Screw lucency: n = 2 (5.9%) Infection: n = 3 Superficial, n = 2 (5.9%) Deep, n = 1 (2.9%) Infection requiring implant removal: n = 2 (5.9%; 1 superficial, 1 deep) Misplaced C-7 screw that seemed to breach the right vertebral foramen: n = 1 (2.9%; no reoperation performed) Overall hardware removal rate: 5/34 (14.7%) Overall reoperation rate: 1/34 (2.9%)
Wellman[24]	One patient complained of neck pain at 5 mo after surgery (then had adjacent segment angulation)	34/35 (97%) achieved solid, radiographically determined fusion after lateral mass plate fixation No violation of the facet joint, vertebral foramen, or spinal canal	No complications associated with the insertion of lateral mass screws No patient experienced vertebral artery or nerve root injury Wound complication, n = 3 (2 wound infections, 1 spinal epidural hematoma) Reoperation for evacuation of spinal epidural hematoma, n = 1 A patient who underwent C5-C7 Axis plating developed progressive angulation after 5 mo that required anterior cervical stabilization Death, n = 1 No patient had screw displacement, broken screws, or broken plates

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TABLE E-3 (*continued*)

Study	Clinical Outcomes	Radiographic Outcomes	Safety
Wu[25]	NR	Radiography at 8-12 wk postop. revealed that 99.1% of patients (114/115) had good osseous fusion No instrumentation failure One patient developed kyphotic deformity and screw self-pullout	No patient required a second procedure to remove or replace malpositioned screws No newly developed neurological deficits after surgery No spinal cord injury or spinal nerve root injury observed postop. No vertebral artery injury No wound infection

*NR = not reported, CSF = cerebrospinal fluid, ASD = adjacent segment disease, VAS = visual analog scale, f/u = follow-up, MRI = magnetic resonance imaging, ADLs = activities of daily living, SSEP = somatosensory evoked potentials, N/A = not applicable, SF-36 = Short Form-36, and NS = not significant. †A = complete motor and sensory loss below level of lesion, B = complete motor and partial sensory loss, C = incomplete (less than grade-3 power) and sensory loss, D = incomplete motor (grade-3 power or greater) and sensory loss, E = normal sensory and motor function. ǂNurick grade: 0 = signs and symptoms of root involvement but without evidence of spinal cord disease; 1 = signs of spinal cord disease but no difficulty in walking; 2 = slight difficulty in walking but does not prevent full-time employment; 3 = severe difficulty in walking that prevents full-time employment and avocation, requires assistive device but does not require a walker; 4 = ability to walk only with assistance of another person or a walker; 5 = chair-bound or bedridden.

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TABLE E-4 Safety Outcomes of Patients with Mixed Diagnoses in the Case Series*

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Local safety				
Surgical site complications				
Superficial infection	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	5.5 (6/110)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	1.3 (1/78)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	2.8 (4/143)
	Stevens[23]	n = 34 Male, 50% Age, 56.3 (39-83)	9	5.9 (2/34)
	Wellman[24]	n = 43 Male, 51% Age, 45.5 (19-81)	25	4.7 (2/43)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/115)
Deep infection	Al Barbarawi[7]	n = 110 Male, 64% Age: 44.8 (16-74)	20.4	0 (0/110)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0.7 (1/143)
	Stevens[23]	n = 34 Male, 50% Age: 56.3 (39-83)	9	2.9 (1/34)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/115)
Hematoma	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0.9 (1/110)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0.7 (1/143)
	Wellman[24]	n = 43 Male, 51% Age, 45.5 (19-81)	25	2.3 (1/43)

TABLE E-4 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Evacuation surgery for hematoma	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/110)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0.7 (1/143)
	Wellman[24]	n = 43 Male, 51% Age, 45.5 (19-81)	25	2.3 (1/43)
Neurological events				
Radiculopathy/C5 nerve root injury or palsy/nerve root pain	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	13.6 (15/110)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	7.7 (6/78)
	Katonis[8]	n = 70 Male, 70% Age, 44 (19-75)	NR	0 (0/70)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0.7 (1/143)
	Wellman[24]	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/43)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/115)
Dural injury/tear	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	5.5 (6/110)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	2.1 (3/143)
CSF leakage	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0.9 (1/110)
	Stevens[23]	n = 34 Male, 50% Age, 56.3 (39-83)	9	2.9 (1/34)

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TABLE E-4 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Neurological adverse events, unspecified	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/110)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	0 (0/78)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/115)
Other complications				
DVT/PE	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	4.5 (5/110)
Death, any	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16–74)	20.4	0.9 (1/110)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	2.8 (4/143)
	Wellman[24]	n = 43 Male, 51% Age, 45.5 (19-81)	25	2.3 (1/43)
Stroke	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/110)
Vertebral artery injury	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/110)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	0 (0/78)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0 (0/143)
	Wellman[24]	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/43)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/115)

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TABLE E-4 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Spinal cord injury	Heller[22]‡	n = 78 Male, NR Age, 52.9 (14-82)	24	2.6 (2/78)
	Katonis[8]	n = 70 Male, 70% Age, 44 (19-75)	NR	0 (0/70)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/115)
Lateral mass fracture	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	1.8 (14/785 screws)
	Ebraheim[21]§	n = 36 Male, 50% Age, NR (16-75)	20.4	2.9 (1/35)
	Katonis[8]	n = 70 Male, 70% Age, 44 (19-75)	NR	3.9 (14/356 screws)
Hardware complications				
Screw/rod pullout	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/505 screws)#
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	0.2 (1/654 screws)
	Katonis[8]	n = 70 Male, 70% Age, 44 (19-75)	NR	0.3 (1/356 screws)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0.6 (6/1026 screws)
	Stevens[23]	n = 34 Male, 50% Age, 56.3 (39-83)	9	0.4 (1/267 screws)
	Wellman[24]**	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/281 screws)
	Wu[25]††	n = 115) Male, 80% Age, 40.6 (18-82	14	0.1 (1/673 screws)

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TABLE E-4 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Screw loosening	Ebraheim[21]	n = 36 Male, 50% Age, NR (16-75)		17.1 (6/35)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	1.1 (7/654 screws)
	Wellman[24]**	n = 43 Male, 51% *Age*, 45.5(19 – 81)	25	0 (0/281 screws)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/673 screws)
Screw/plate breakage	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/505 screws)#
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	0.5 (3/654 screws)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0.5 (5/1026 screws)
	Wellman[24]**	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/281 screws)
	Wu[25]	n = 115 Male, 80% Age, 40.6 (18-82)	14	0 (0/673 screws)
Screw lucency	Stevens[23]	n = 34 Male, 50% Age, 56.3 (39-83)	9	0.7 (2/267 screws)
Screw violating facet joint	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	1.0 (8/785 screws)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	0.2 (1/654)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0.8 (8/1026 screws)

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TABLE E-4 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
	Wellman[24]**	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/281 screws)
Screw violating vertebral foramen	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0.6 (5/785 screws)
	Katonis[8]	n = 70 Male, 70% Age, 44 (19-75)	NR	1.4 (5/356 screws)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	1.9 (20/1026 screws)
	Stevens[23]	n = 34 Male, 50% Age, 56.3 (39-83)	9	0.4 (1/267 screws)
	Wellman[24]**	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/281 screws)
Screw violating spinal canal	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/785 screws)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	0 (0/1026 screws)
	Wellman[24]**	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/281 screws)
Subsequent surgery				
Revision: surgery that modified or adjusted the original implant because of signs and symptoms such as pain, radiculopathy, etc.	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0.9 (1/110)
Hardware removal/adjustment: surgery to correct malpositioned screws, screw breakout, or loosening	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	1.8 (14/785 screws)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	1.1 (7/654 screws)
	Stevens[23]	n = 34 Male, 50% Age, 56.3 (39-83)	9	1.9 (5/267)

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TABLE E-4 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
	Wellman[24]**	n = 43 Male, 51% Age, 45.5 (19-81)	25	0 (0/281 screws)
Supplemental fixation: surgery to provide additional stabilization to the index site	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	1.3 (1/78)
Reoperation: additional procedure at the index level other than a revision, hardware removal, or supplemental fixation††	Al Barbarawi[7]	n = 110 Male, 64% Age, 44.8 (16-74)	20.4	0 (0/110)
	Heller[22]	n = 78 Male, NR Age, 52.9 (14-82)	24	2.6 (2/78)
	Sekhon[5]	n = 143 Male, 61% Age, 56.8 (12-96)	24	1.4 (2/143)
	Stevens[23]	n = 34 Male, 50% Age, 56.3 (39-83)	9	2.9 (1/34)
	Wellman[24]**	n = 43 Male, 51% Age, 45.5 (19-81)	25	4.7 (2/43)

*NR = not reported. †The values for the age in years are given as the mean, with the range of means in the individual studies in parentheses. ‡Not attributable to screw insertion. §In a patient with osteoporosis and tumor involvement resulting in massive destruction of vertebral body and lamina. #Screw pullout or breakage was assessed in only 505 of the 785 placed screws as reported in Table E-3. **Includes 22 C7 pedicle screws. ††In a patient who developed kyphotic deformity resulting in self-pullout of the screws. ‡‡To include surgery for adjacent segment degeneration, evacuation of hematoma, cerebrospinal fluid leakage, and anterior cervical stabilization.

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TABLE E-5 Safety Outcomes of Patients with Spondylosis in the Case Series*

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Local safety				
Surgical site complications				
Superficial infection	Cabraja[13]	n = 24 Male, 71% Age, 66.2 (45-84)	28	4.2 (1/24)
	Eubanks[14]‡	n = 158 Male, 59% Age, 61 (35-87)	14.5	2.5 (4/158)
	Houten[16]	n = 38 Male, 66% Age, 65 (41-86)	30.2	2.6 (1/38)
	Huang[17]	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	9.4 (3/32)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0 (0/225)
	Liu[19]	n = 38 Male, 24% Age, 45 (24-60)	28	7.9 (3/38)
Deep infection	Cabraja[13]§	n = 24 Male, 71% Age, 66.2 (45-84)	28	4.2 (1/24)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0 (0/225)
Hematoma/seroma	Eubanks[14]‡	n = 158 Male, 59% Age, 61 (35-87)	14.5	0.6 (1/158)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0.9 (2/225)
	Kumar[18]	n = 25 Male, 68% Age, 60 (33-79)	47.5	4.0 (1/25)
Evacuation surgery for hematoma	Eubanks[14]‡	n = 158 Male, 59% Age, 61 (35-87)	14.5	0.6 (1/158)
Dysphagia	Eubanks[14]‡	n = 158 Male, 59% Age, 61 (35-87)	14.5	0.6 (1/158)

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TABLE E-5 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Neurological events				
Radiculopathy/C5 nerve root palsy or injury	Eubanks[14]‡	n = 158 Male, 59% Age, 61 (35-87)	14.5	4.4 (7/158)
	Houten[16]	n = 38 Male, 66% Age, 65 (41-86)	30.2	2.6 (1/38)
	Huang[17]	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	6.3 (2/32)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	3.6 (8/225)
Dural injury/tear	Katonis[9]	n = 225 Male, 53% Age: 68 (45-84)	18	0 (0/225)
Neurological adverse events, unspecified	Huang[17]	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	0 (0/32)
	Kumar[18]	n = 25 Male, 68% Age, 60 (33-79)	47.5	4.0 (1/25)
Other complications				
Death (any)	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0 (0/225)
Vertebral artery injury	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0 (0/225)
Spinal cord injury	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0 (0/225)
Lateral mass fracture	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	1.6 (27/1662 screws)
Hardware complications				
Screw/rod pullout	Houten[16]	n = 38 Male, 66% Age, 65 (41-86)	30.2	13.2 (5/38)
	Huang[17]	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	6.3 (2/32)

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TABLE E-5 (*continued*)

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0.2 (3/1662 screws)
Screw/plate breakage	Houten[16]	n = 38 Male, 66% Age, 65 (41-86)	30.2	7.9 (3/38)
	Huang[17]	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	3.1 (1/32)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	0 (0/1662 screws)
Screw violating vertebral foramen	Houten[16]	n = 38 Male, 66% Age, 65 (41-86)	30.2	2.6 (1/38)
Subsequent surgery				
Revision: surgery that modified or adjusted the original implant because of signs and symptoms such as pain, radiculopathy, etc.	Cabraja[13]	n = 24 Male, 71% Age, 66.2 (45-84)	28	8.3 (2/24)
	Huang[17]	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	3.2 (1/31)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	1.3 (3/225)
Hardware removal/adjustment: surgery to correct malpositioned screws, screw breakout or loosening	Eubanks[14]‡	n = 158 Male, 59% Age, 61 (35-87)	14.5	0.6 (1/158)
	Houten[16]	n = 38 Male, 66% Age, 65 (41-86)	30.2	2.6 (1/38)
Reoperation: additional procedure at the index level other than a revision, hardware removal, or supplemental fixation	Highsmith[15]	n = 15# Male, NR** Age, 58 (42-81)**	41.3	13.3 (2/15)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	6.2 (14/225)

*NR = not reported. †The values for the age in years are given as the mean, with the range of means in the individual studies in parentheses. ‡Comparative study designed to assess the impact of smoking on fusion rates in posterior cervical fusion with lateral mass instrumentation; therefore, 26% (41/158) of the population were smokers. §Cerebrospinal fluid fistula. #Reflects the number of patients following exclusion of any cervicothoracic fusions (n = 11 C7 fusions extended to T1). The reoperation rate was reported separately for these 15 patients. **Demographics were only for the entire group of 26 patients who received posterior fusion and lateral mass plating.

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TABLE E-6 Safety Outcomes of Patients with Trauma in the Case Series

Outcome	Studies	Demographics*	Risk *(% [n/N])*
Local safety			
Surgical site complications			
Superficial infection	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	4.5 (2/44)
	Pateder[20]	n = 34 Male, 59% Age, 41 (18-85)	10.3 (3/29)
Deep infection	Pateder[20]	n = 29 Male, 59% Age, 41 (18-85)	3.4 (1/29)
Neurological events			
C5 nerve root palsy/injury	Pateder[20]	n = 29 Male, 59% Age, 41 (18-85)	3.4 (1/29)
Neurological adverse events, unspecified	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	0 (0/44)
Other complications			
DVT	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	4.5 (2/44)
Death, any†	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	4.5 (2/44)
Vertebral artery injury	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	0 (0/44)
Hardware complications			
Screw loosening	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	3.8 (8/210 screws)
Subsequent surgery			
Revision: surgery that modified or adjusted the original implant because of signs and symptoms such as pain, radiculopathy, etc.	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	6.8 (3/44)
Hardware removal/adjustment: surgery to correct malpositioned screws, screw breakout or loosening	Pateder[20]	n = 29 Male, 59% Age, 41 (18-85)	0.1 (1/198 screws)
Reoperation: additional procedure at the index level other than a revision, hardware removal, or supplemental fixation	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	2.3 (1/44)

TABLE E-6 (*continued*)

Outcome	Studies	Demographics*	Risk *(% [n/N])*
	Pateder[20]	n = 29 Male, 59% Age, 41 (18-85)	10.3 (3/29)

*The values for the age in years are given as the mean, with the range of means in the individual studies in parentheses. †All deaths unrelated to procedure: 1 preexisting Crohn disease complication, 2 pneumonia and respiratory failure.

TABLE E-7 Effectiveness Outcomes of Patients with Mixed Diagnoses in the Case Series*

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Fusion	Ebraheim[21]†	n = 36 Male, 50% Age, NR (16-75)	17	100% (35/35)
	Katonis[8]	n = 70 Male, 70% Age, 44 (19-75)	Min. 24	91.4% (64/70)
	Stevens[23]§	n = 34 Male, 50% Age, 56.3 (39-83)	9	100% (16/16)
	Wellman[24]#	n = 43 Male, 51% Age, 45.5 (19-81)	25	97.1% (34/35)
	Wu[25]**	n = 115 Male, 80% Age, 40.6 (18-82)	14	99.1% (114/115)
Pain	Ebraheim[21]	n = 36 Male, 50% Age, NR (16-75)	17	Good to excellent pain relief in 100% of patients
	Katonis[8]	n = 70 Male, 70% Age, 44 (19-75)	Min. 24	Most patients characterized their postop pain as mild; non-narcotic analgesic use only
	Wellman[24]#	n = 43 Male, 51% Age, 45.5 (19-81)	25	Neck pain 5 mo postop.: 2.9% (1/35)

*NR = not reported. †The values for the age in years are given as the mean, with the range of means in the individual studies in parentheses. ‡35/36 patients (97.2%) were followed until clinical and radiographic union was achieved. §Radiographic evidence of fusion on dynamic plain roentgenograms and/or axial CT was assessed in patients available for follow-up longer than 6 mo (n = 16; 45.7%). #35/43 patients (81.4%) available for follow-up. **All fusions achieved by 8-12 wk postop.

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TABLE E-8 Effectiveness Outcomes of Patients with Spondylosis in the Case Series*

Outcome	Study	Demographics†	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Fusion	Huang[17]‡	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	96.8% (30/31)
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	97.3% (219/225)
	Liu[19]	n = 38 Male, 24% Age, 45 (24-60)	28	100% (38/38)
Pain	Cabraja[13]	n = 24 Male, 71% Age, 66.2 (45-84)	28	VAS scores Preop.: 4.4 ± 1.1 Last f/u: 3.6 ± 0.9 P < 0.001
	Katonis[9]	n = 225 Male, 53% Age, 68 (45-84)	18	Most patients characterized their postop pain as mild; non-narcotic analgesic use only
Function				
Nurick grade	Huang[17]	n = 32 Male, 75% Age, 67.8 (50-79)	15.2	Preop.: 2.6 (1-4) Last f/u: 1.8 (0-3) P < 0.001
mJOA scale	Cabraja[13]	n = 24 Male, 71% Age, 66.2 (45-84)	28	Preop.: 11.7 ± 3.2 Last f/u: 14.9 ± 3.2 P < 0.001
	Houten[16]	n = 38 Male, 66% Age, 65 (41-86)	30.2	Preop.: 12.9 Last f/u: 15.6 P < 0.001
Odom criteria excellent or good	Cabraja[13]	n = 24 Male, 71% Age, 66.2 (45-84)	28	97% (37/38) improved 83.3% (20/24)
	Eubanks[14]	n = 158 Male, 59% Age, 61 (35-87)	14.5	79.7% (126/158)

*VAS = visual analog scale, and f/u = follow-up. †The values for the age in years are given as the mean, with the range of means in the individual studies in parentheses. ‡31/32 patients followed for >6 mo. All patients achieved radiographic fusion at final f/u; however, one patient required a second procedure to achieve fusion and thus was not considered to have had a successful fusion.

TABLE E-9 Effectiveness Outcomes of Patients with Trauma in the Case Series

Outcome	Studies	Demographics*	Mean Follow-up *(mo)*	Risk *(% [n/N])*
Fusion	Fehlings[2]†	n = 44 Male, 84% Age, 32.4 (16-80)	45.6	92.7% (38/41)
Pain	Fehlings[2]	n = 44 Male, 84% Age, 32.4 (16-80)	45.6	Neck pain requiring analgesics or interfering with activities of daily living: 5.3% (2/38)
ASIA score	Fehlings[2]‡	n = 44 Male, 84% Age, 32.4 (16-80)	45.6	Improved: 25.7% (9/35) Worse: 0% (0/35)

*The values for the age in years are given as the mean, with the range of means in the individual studies in parentheses. †Fusion was assessed in patients with >6 mo follow-up (41/44; 93.2%). ‡35/44 patients had preop. and final follow-up ASIA scores.

TABLE E-10 Complications of Lateral Mass Screw Fixation Utilizing Plates Compared with Rods

	Plates			Rods				
	Studies	Cases/N	Risk (95% CI) *(%)*	Studies	Cases/N	Risk (95% CI) *(%)*	Risk Difference (95% CI)*	P Value
Nerve injury (all causes)								
Per patient	5[8,16,17,22,24]	9/261	3.45 (1.23, 5.66)	3[7,14,25]	22/383	5.74 (3.41, 8.07)	−2.30 (−5.51, 0.01)	0.182
Per screw	3[8,22,24]	6/1291	0.46 (0.09, 0.84)	2[7,25]	15/1458	1.03 (0.51, 1.55)	−0.56 (−1.20, 0.07)	0.090
Nerve injury caused by screw								
Per patient	4[8,17,22,24]	4/223	1.79 (0.05, 3.54)	2[7,25]	1/225	0.44 (0.00, 1.31)	1.35 (−0.60, 3.30)	0.174
Per screw	3[8,22,24]	4/1291	0.31 (0.01, 0.61)	2[7,25]	1/1458	0.07 (0.00, 0.20)	0.24 (−0.09, 0.57)	0.139
Screw/rod pullout								
Per patient	5[8,16,17,22,24]	9/261	3.45 (1.23, 5.66)	3[7,23,25]	2/259	0.77 (0.00, 1.84)	2.67 (0.20, 5.10)	0.034
Per screw	3[8,22,24]	2/1291	0.15 (0.00, 0.37)	3[7,23,25]	2/1445	0.14 (0.00, 0.33)	0.02 (−0.27, 0.30)	0.910
Screw/plate breakage								
Per patient	4[16,17,22,24]	7/191	3.66 (1.00, 6.33)	2[7,25]	0/225	0.00 (0.00, 1.33)	3.66 (1.00, 6.33)	0.004
Per screw	2[22,24]	3/935	0.32 (0.00, 0.68)	2[7,25]	0/1178	0.00 (0.00, 0.25)	0.32 (−0.04, 0.68)	0.052
Revision								
Per patient	2[2,17]	4/76	5.26 (0.24, 10.28)	2[7,13]	3/134	2.24 (0.00, 4.74)	3.02 (−2.59, 8.63)	0.241
Hardware removal								
Per patient	2[22,24]	7/121	5.79 (1.63, 9.94)	2[7,23]	19/144	13.19 (7.67, 18.72)	−7.41 (−14.33, −0.49)	0.043
Per screw	2[22,24]	7/935	0.75 (0.20, 1.30)	2[7,23]	19/1052	1.81 (1.00, 2.61)	−1.06 (−2.03, −0.08)	0.038
Reoperation								
Per patient	3[2,22,24]	5/165	3.03 (0.41, 5.65)	3[7,15,23]	3/159	1.89 (0.00, 4.00)	1.14 (−2.22, 4.51)	0.507
Per screw	2[22,24]	4/935	0.43 (0.01, 0.85)	2[7,23]	1/342	0.29 (0.00, 0.86)	0.14 (−0.57, 0.84)	0.732
Screw violating vertebral foramen								
Per patient	3[8,16,24]	6/151	3.97 (0.86, 7.09)	2[7,23]	6/144	4.17 (0.90, 7.43)	−0.19 (−4.71, 4.32)	0.933
Per screw	2[8,24]	5/637	0.78 (0.10, 1.47)	2[7,23]	6/1052	0.57 (0.12, 1.03)	0.21 (−0.61, 1.04)	0.595

*A negative number favors plate fixation, and a positive number favors rod fixation.